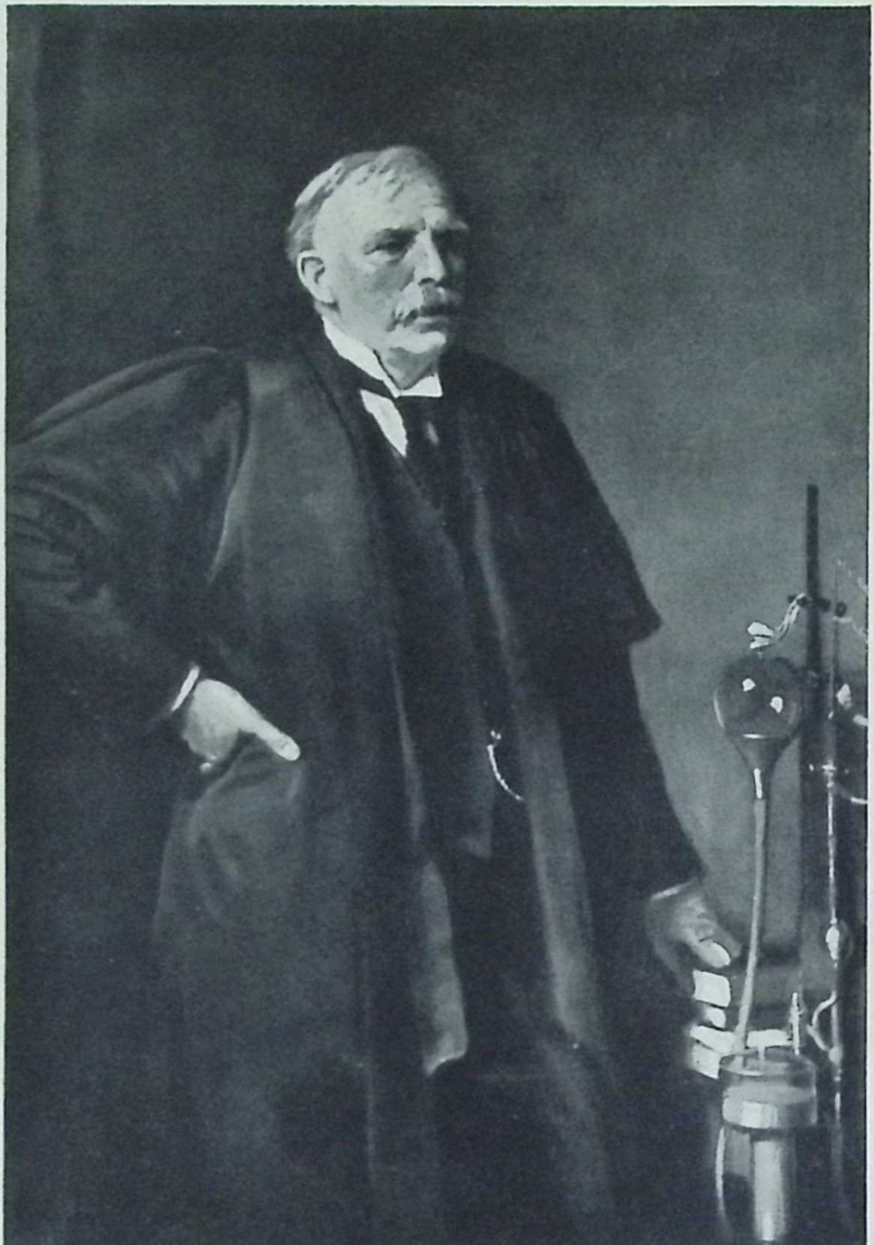
# INDUSTRIAL RESEARCH AND DEVELOPMENT IN THE UNITED KINGDOM

## A SURVEY



Lord Rutherford of Nelson, O.M., F.R.S.
President of the Royal Society 1925–30. Chairman of Advisory Council, Dept. of Scientific and Industrial Research 1930–37.
Painting by Oswald Birley.

# INDUSTRIAL RESEARCH AND DEVELOPMENT

## IN THE UNITED KINGDOM

### A SURVEY

by

SIR H. FRANK HEATH

G.B.E., K.C.B.

and

A. L. HETHERINGTON

C.B.E.



FABER AND FABER LIMITED
24 Russell Square
London

*First published in Mcmxlvi*
*by Faber and Faber Limited*
*24 Russell Square London W.C. 1*
*Printed in Great Britain by*
*R. MacLehose and Company Limited*
*The University Press Glasgow*

# PREFACE

It would have been impossible to produce this book without the active and sympathetic help of many people.

In the first place we are deeply indebted to all the officials connected with the many research establishments under Government referred to in the text. To all these old colleagues and friends we tender our grateful thanks but owing to the etiquette of the Service their names are not included below.

Similarly we are beholden to the members of the staffs of the various Research Associations for invaluable assistance in the preparation of the accounts of the industries with which they are concerned. We owe no less grateful thanks to many friends connected with industry for the help they also have given in the preparation of this survey. The names of all these friends are given in the appended list of acknowledgments.

We are also very grateful to H. M. Stationery Office, to several Art Galleries, Institutions and industrial firms for permission to reproduee the illustrations in this book. Their names are recorded in the list of illustrations on page xi.

At the same time we wish to emphasise that we alone must be held responsible for any criticisms or suggestions to be found in this book and for any errors of fact that may have crept into the text.

We are specially indebted to Sir Frank Gill for the brief but simple statement of the method of applying the principles of Quality Control in actual practice. It will be found in Appendix VII. We also wish to thank Miss E. S. Durrad for preparing an Index, without which a book of this kind would be almost useless.

H. F. H.

*December*, 1944 A. L. H.

*Postscript.*—Since the above was written and during the passage of the book through the press a number of important inventions and discoveries previously on the secret list have been made public, and various problems we have discussed have been the subject of Government decisions. A description of these was therefore impossible and must await the issue of a later edition if the demand should justify it.

H. F. H.

*October*, 1945 A. L. H.

# CONTENTS

## PART III. GOVERNMENT ACTION



## PART IV. INDEPENDENT INSTITUTIONS AFFECTING INDUSTRIAL PROGRESS

## CONTENTS



## PART V. GENERAL FACTORS AFFECTING INDUSTRIAL PROGRESS



## APPENDICES

# ILLUSTRATIONS

# ACKNOWLEDGMENTS

Bailey, Mr. G. L. (Non-Ferrous Metals); Battle, Mr. G. J. N. (Sugar); Belch, Mr. A. (Shipbuilding); Bell, Dr. S. H. (Paint); Bennett, Mr. J. G. (Coal); Bentley, Mr. T. L. J. (Photography); Bird, Mr. H. (Brewing); Bradley, Mr. H. (Boots and Shoes); Bull, Mr. S. W. E. (Scientific Personnel); Campbell, Dr. L. E. (Confectionery and Manufactured Foods); Chance, Sir Hugh (Glass); Clement, Mr. P. E. (Shipping and Shipbuilding); Cooper, Mr. W. T. (Coal); Cowie, Mr. J. R. (Electricity); Cramond, Mr. G. A. (Paper-making); Cronshaw, Dr. C. J. T. (Chemical); Dawson, Mr. T. R. (Rubber); Day, Mr. Chas. (Internal Combustion Engines); Desch, Dr. C. H., F.R.S. (Iron and Steel); Dunsheath, Dr. P. (Electricity); Dunstan, Dr. A. E. (Oil); Evans, Mr. E. C. (Iron and Steel); Everitt, Mr. P. F. (Navigation); Fenelon, Mr. K. G. (Production Engineering); Fleming, Sir A. P. M., C.B.E. (Electricity); Francis, Dr. M. (Pottery); Giffen, Dr. E. (Automobile); Graham, Mr. Ivon (Coal), Green, Mr. A. T. (Refractories); Harvey, Mr. A. (Leather); Harwood, Mr. F. C. (Laundry); Hayes, Mr. L. W. (Broadcasting); Herbert, Mr. T. M. (Railways); Hughes, Mr. A. J. (Scientific Instruments); Jones, Mr. W. Idris (Coal); Jordan, Dr. L. A. (Paint); Jordan Lloyd, Miss D. (Leather); King, Dr. J. G. (Gas); Lanchester, Mr. G. (Automobile); Larke, Sir William, K.B.E. (Iron and Steel); McCance, Dr. A., F.R.S. (Iron and Steel and Scientific Personnel); Macara, Mr. T. (Confectionery and Manufactured Foods); Marsh, Dr. H. C. (Scientific Instruments); Meynell, Mr. Francis (Industrial Design); Moon, Mr. A. Ramsay (Welding); Moore, Dr. H. (Glass); Moran, Dr. T. (Flour Milling); Paterson, Dr. C. C., O.B.E., F.R.S. (Electricity); Paterson, Mr. J. H. (Welding); Pearce, Mr. J. G. (Iron-founding); Pendred, Mr. L. St. L., C.B.E. (General Engineering); Philpot, Mr. A. J., O.B.E. (Scientific Instruments); Poulsen, Mr. C. M. (Aircraft); Pye, Dr. D. R., C.B., F.R.S. (Aircraft); Riddell, Dr. G. R. (Printing); Schultze, Mr. R. S. (Photography); Shoenberg, Dr. J. (Television); Smith, Mr. Raymond (City Companies); Smith, Dr. S. L. (Shipbuilding); Taylor, Mr. E. Wilfred (Scientific Instruments); Taylor, Mr. M. H. (Scientific Instruments); Toy, Dr. F. C. (Cotton, Silk and Rayon); Turner, Dr. A. J. (Linen); Turner, Prof. W. E. S., F.R.S. (Glass); Twyman, Mr. F., F.R.S. (Scientific Instruments); Walker, Mr. D. D. (Scientific Instruments); Warren, Mr. H. (Electricity); Wedmore, Mr. E. B., C.B.E. (Electricity); Wickenden, Mr. H. (Sugar); Wicks, Mr. C. V. (Sugar); Wilsdon, Mr. B. H. (Wool); Wimperis, Mr. H. E., C.B., C.B.E. (Air Navigation); Wright, Mr. C. H. (Scientific Instruments).

# CHAPTER I

# GENERAL INTRODUCTION

This is not a book written either by or for experts. It is intended for the intelligent layman who has probably realised only partially the large share this country has had in the progress made in the establishment of modern conditions of life as they exist around him, and not less for those engaged in their own particular industry who have had little opportunity to learn what has been and is being done in other industrial fields. The aim has been to give a fair picture of the position and while drawing attention to some of its weaknesses to indicate the many directions in which this country has led, and still leads, in industrial progress.

The progress of industrial research and invention, with the subsequent increase in mechanisation, has influenced profoundly domestic life in this and other countries. The life of the housewife today (in times of peace) is very different from that of her grandmother, still more so from that of her great-grandmother. Fifty to a hundred years ago, the housewife made the clothes for the family, often weaving the cloth and, until the invention of the sewing-machine about 1850, sewing everything by hand. The house was cleaned by hand and foods were preserved and stored by the housewife herself. She walked, or drove by horse vehicle. Today, in towns or in many country districts, there are no lamps for her to trim, no fires to lay, and no food preservation to undertake if advantage is taken of the efforts of others. The weekly laundry can be dealt with by another agency; the floors can be swept by a vacuum cleaner and every form of garment can be purchased reasonably in a shop. For trivial sums considerable journeys can be made rapidly. A dependence on the ingenuity of others has been created and attachment to the home has been lessened by the lure of external attractions offered by theatre, cinema, concert or sports. With this greater freedom from insistent duties in and for the household, there is inevitably a loss of self-reliance and the acceptance of assistance from the State or municipality in matters which formerly were the duty and the prerogative of the individual.

On the other hand, immense advantages have been secured which have added materially to human longevity and to freedom from sickness. Copious supplies of pure piped water are available at any rate in the towns, where improved sanitation and improved heating and ventilation have been provided. The strain on the eyes has been considerably lessened by increased illumination. Between the dates of the

carbon filament and the tungsten filament lamp, a householder obtained, at no additional cost to himself, four times the yield of light per unit of electric power. With a 25 watt lamp he could have its light for six hours a day for a whole week at the pre-war price of a box of matches. The advances in the knowledge of medicine and of the nutritional needs of children have been very great, as the falling rates of mortality prove. Gradually the provision of better dwelling houses is being taken in hand. The advances in the mechanisation of transport, including air transport, are equally striking. On the railways, for instance, the number of passenger journeys by persons other than season ticket holders was already 604,000,000 in 1880. By 1905 the number of passenger journeys had nearly doubled and, though the number was about the same twenty-five years later, the total of motor vehicles on the roads in 1928 was over 1,300,000 as compared with only 176,000 sixteen years earlier though the roads had grown by less than 3,000 out of a total of 179,000 miles.

How did this change in our habits and behaviour come about? In the first instance undoubtedly through the initiative and research of our manufacturing industries with the help of men of inventive genius or of scientific training and imagination. H. A. L. Fisher pointed out, in his *History of Europe* (Chap. LXXX, p. 1012) in speaking of International Currents, the desire of the British industrialist 'to be free of government meddling and to be allowed to get rich in his own way'. The assistance of the inventor and man of science made many British industries able to maintain the lead in the markets of the world which the introduction of steam power had first won for them.

Indeed the initiative of our scientists and inventors was no less than that of our manufacturers. Already in the 17th century the Royal Society had been founded and Cromwell had written 'To be a Seeker is to be of the best Sect next to a Finder and such an one shall every faithful humble seeker be at the end. Happy seeker, happy finder.' The seeker after scientific truth enjoys the same thrills and suffers the same disappointments as the explorer, but unlike Columbus, he is not in modern times consigned as a result of his labours to chains and obloquy by a Bobadilla appointed by Government. Or is he? The objurgations sometimes levelled at men of science, especially during periods of industrial depression like those of the 1930's, prompt the question. It was contended in the last great depression, in private and in public, that the evils of unemployment were largely due to the zeal of scientists who, by designing improved methods of production, diminished the demand for labour; or that their investigations only led to new ways in which the human race, combatant and non-combatant, could be more expeditiously destroyed in war. It was more or less seriously suggested that it would be a good thing if a five or ten year holiday were accorded to scientists.

The same kind of outcry was made when, for instance, improved gas appliances were devised. These consumed much less gas than the previous types; the consumption of gas would go down and the gas companies, and their shareholders, would suffer. In point of fact, the reverse happened. The improved appliances led to a wider use of this means of cooking the family dinner and of lighting the home, and gas consumption rose. While the first effect of a scientific discovery and its development may result in a readjustment of labour, the ultimate result must be a higher standard of living, betterment of social conditions and fuller employment. Clear evidence of the process is shown, for example, in the account of the progress made in the electrical industry (p. 42). When intellectual Luddites, prompted by the woes of the moment, give vent to obscurantist views, they should be reminded of the lesson taught by Canute to his courtiers. It is idle to imagine that Nature and human progress can be enchained.

The suspicion of scientific research felt by some of the public especially in difficult times, is accompanied too often by a misunderstanding by the manufacturer of its significance for the nation. The industrialist may be alive to the need for keeping in the forefront with his products and the necessity for using the latest inventions and discoveries. He has often been content to purchase a licence to use them from the foreign patentee because this seems to be the quickest way and therefore the cheapest means of using science for his purposes. But apart from the discouragement thus caused to the native inventor and research worker, the effect of this action is to increase the balance of payments due from this country for imports. Moreover the tendency is encouraged to increase the export of raw materials such as coal—a diminishing asset—or semi-manufactured articles, in order to balance our trade. Our industrial workers to that extent are transferred from the more highly skilled occupations to those involving less training and lower intellectual capacity. In a word, the neglect of scientific research tends to make our people hewers of wood and drawers of water for nations that put more brain work into their products.

But that is not all. The safety of the nation may be involved. The impact of war revealed startling deficiencies in the set-up of private endeavour and soon after the outbreak of World War I the Board of Trade appointed a committee under the chairmanship of the late Lord Haldane to 'consider and advise as to the best means of obtaining for the use of British industries, sufficient supplies of chemical products, colours and dyestuffs of kinds hitherto largely imported from countries with which we are at present at war.' The Royal Society and other learned bodies interested in chemical research were received in deputation by the Presidents of the Board of Trade and of the Board of Education

B

in May 1915 and urged the 'establishment of a National Chemical Advisory Committee' to promote closer relations between the manufacturers and scientific workers and teachers with the active support of Government. This deputation was immediately followed by the appointment of an Advisory Council for Scientific and Industrial Research with far wider terms of reference and, in 1916, by the foundation of the Department of Scientific and Industrial Research under the Lord President of the Council.

So it came about that Government began to take an active interest in industrial research. A similar interest had already shown itself in research for agriculture when the Development Commission was appointed in 1909 and somewhat later in medical research in connexion with the Act for health insurance passed in 1911. Both fields of research and the share of Government in them were greatly extended between World Wars I and II, and since then, but they fall outside the scope of this book.

The plan of the present work falls into the following main parts: Part I: Productive Industries; Part II: Research for the Community; Part III: Government Action; Part IV: Independent Institutions affecting Industrial Progress; Part V: General Factors affecting Industrial Progress.

# PART I

# PRODUCTIVE INDUSTRIES

## CHAPTER 2

## INTRODUCTORY NOTE

Under the term 'Productive Industry' are included undertakings engaged in making consumer and capital goods.

Interest in industrial research is today great and growing. A committee of over 100 members of both Houses of Parliament, with representatives of certain scientific and technical institutions, has studied our present needs and has made important and far-reaching recommendations to the Government for additional large expenditure in its support, especially through the Department of Scientific and Industrial Research (October, 1943). The Industrial Research Committee of the Federation of British Industries issued a reasoned report to the same end in that same month. Similarly, Nuffield College, Oxford, in April 1944, issued a long 'Statement on Problems of Scientific and Industrial Research' dealing with the many aspects of the problems involved, and the Chancellor of the Exchequer laid before Parliament a White Paper describing existing Government machinery for the promotion of scientific research and development. Further, a number of distinguished men of science have sent letters to the daily press on the subject, among them the President of the Royal Society who pointed out, like the authors of the Nuffield Report, the pressing necessity for extending and developing the nation's provision for higher technical education.

A similar need was felt and expressed in 1915, but the present struggle has impressed both men of science and industrialists with a far deeper and wider realisation of the national shortcomings—especially as the result of economic warfare which is far more complex and difficult than it was a generation ago and has brought to the front our economic relations with the British Commonwealth of Nations and its Allies, in particular the United States of America.

Indeed, it is now apparent that the application of science to industry is neither a single problem nor susceptible of the same methods over the whole field. Not only are different industries basically varied in the

materials they use and the processes they employ, but the national individualism has encouraged, since the breakdown of the craft guilds, the belief that trade processes were the private knowledge of the individual firm to an extent far exceeding the facts. The so-called staple industries were essentially crafts and, being handicrafts, whether boat-building or masonry or weaving or metal-working, were originally mechanical in method. Industries of later origin have been based on scientific discovery, and though they have used mechanical devices, and their progress has depended on the development of mechanism, they are not fundamentally crafts. Hence the difference often remarked between the relatively slow advance of industrial research in the older when compared with the newer industries, such as the chemical and electrical. The crafts no doubt have in the course of time increasingly used the results of scientific research, and the industries based fundamentally on scientific research have increasingly depended on machinery, but the distinction is valid. Advance in the crafts has been due in the main to the inventions made by individual workers. Advance in the scientific industries has called increasingly for researches undertaken by teams of scientific investigators.

The distinction must not be drawn too rigidly, for progress in engineering, essentially a craft in origin, was at least at one stage definitely held up by the lack of strictly scientific research. James Watt found the power output of his steam engine so diminished by the apparent impossibility of achieving a close fit of the piston in its cylinder that he was driven to use his beaver hat in order to make it steam-tight. Increased capacity for accurate measurement has lain at the bottom of engineering advance equally with the discovery of new higher-duty alloys by the metallurgist. But none the less, engineering is fundamentally a craft. So it came about naturally that progress in the crafts was due to the single inventor in the first instance. Hargreaves' spinning-jenny, Arkwright's spinning frame, Crompton's spinning mule and Jacquard's loom were individual discoveries. Invention is an achievement reached without necessarily a great deal of formal training and sometimes in apparent contradiction of existing scientific theory. Research work requires organised knowledge and use of facts, principles and scientific methods and is increasingly due to the co-operation of a team of scientists often including workers in different scientific fields. The modern radio-location device cannot be described as due to a single mind. We owe, it is true, the multi-stage reaction steam turbine to the inventive genius of Parsons, who was a great scientific engineer as well as an inventor, just as William Perkin, the first discoverer and manufacturer of aniline mauve and other coal-tar dyes was essentially a research chemist. Yet modern engineering, like the present-day chemical industry, or the

electrical industry, relies increasingly on the team work of large groups of research workers, though the scope for invention remains an important part of engineering progress.

The position to be faced in the post-war period must be judged with a realisation of the way our industries have developed, and especially of the way in which in the past this country led the world in many fields. Nor should we forget the great and successful endeavours of many of our leading firms to secure, by means of research, the high quality of their manufactures. Self depreciation is one form of the under-statement to which we are addicted and it is encouraged by the greatly advertised achievements in other countries and especially by their estimated expenditure on industrial research. The industrialists of this country are consequently pictured as sitting with folded hands waiting for the clouds to roll by. This is not so, for individual firms both in the basically craft industries and in those based essentially on science had for many years before World War I conducted successful research and they needed no missionary efforts on its behalf. Moreover, since that war they have combined in co-operative organisations to undertake scientific investigations for the benefit of their industry as a whole and greatly extended their own private efforts, though we shall endeavour to show that much more needs to be done, and must be done, if the well-being of the country and its dominions and colonies is to be secured in the years ahead.

The industries of this country are, as we have already suggested, very different in their historical growth, their varying dependence on craftsmanship, on invention or on research; besides being influenced by a complexity of economic conditions. Unless these factors are taken into account, progress will not be made and any attempt to find a solution will inevitably fail. The League of Nations undertook a Sisyphean task on the assumption that numerous nations, in different stages of development, all with varying histories behind their creation and with vastly different degrees of power at their command, could sit round a table and by unanimous vote find a common formula to solve the problems of peace and its preservation. Similarly it is, in our view, ludicrous to think that the methods employed in America, for instance, with a home market three times the size of ours, are likely to solve the problems of British industry. Nor is a Procrustean bed, into which the industrial body politic of this country should be fitted, a form of utility furniture likely to meet our future needs.

Part I of this book is devoted to short descriptions of some of the main industries of this country, other than those concerned with agriculture and medicine. The descriptions are required to bring out the great complexity of the problem as a whole and to indicate the wide

variety of circumstances which have led to development and progress in the main industrial activities of the country. Unless these are appreciated, it is difficult to realise how many considerations must be taken into account and how impossible it is to find sovereign remedies for the ills that exist.

Considerations of space make it impossible to deal thoroughly with all the industrial activities of the country, on the progress of which the national prosperity depends; and it is only possible to present a few of the landmarks of the more important industries in brief sketches. These serve, however, to bring out some of the strengths of the country and some of its weaknesses. The broad result is to convey the impression that much remains to be done by way of research and development to extend, or even to retain, our industrial position especially in regard to our export trade. Fortunately, in recent years, industrialists and the country at large have become increasingly alive to that necessity. The reader cannot fail to discern from these brief outlines how war has been, and is, a stimulus to scientific endeavour which, when rightly used, can be made to serve the needs of peace; but these needs and their satisfaction are far more difficult and complex than those of war. A higher standard of living and better social conditions are pious aspirations and often but little more. The stern arbitrament of total war which involves the survival of the fittest, calls for more urgent attention to national efficiency and because it leads to national unity of purpose, calls forth rapid advances in knowledge and attainment far exceeding those normally possible. But these advances, many of them of a surprising kind, are still under the bond of secrecy for reasons of security and cannot be described in this book.

It will be noticed that the accounts of the several industries selected for notice are very different in length. This must not be thought to suggest their respective importance in the national economy. It results partly from the fact, already indicated, that much recent scientific advance cannot yet be made known, partly because the amount of industrial research and development that has yet taken place varies in different trades.

# CHAPTER 3
# AUTOMOBILE

## *Early years*

Automobile history began in this country about 1894 when a small number of enthusiasts imported cars of various types from the continent. Prior to 1898 obstructive legislation, known as the red flag enactment, deterred British engineers from devoting their inventive skill to the new form of locomotion, thus giving continental nations (mainly Germany and France) some ten or twelve years in which to develop the new industry, before its inception in Great Britain. In spite of this advantage to their competitors, British engineers began to devote their energy to automobile design but with no established type to guide them. Types differed in almost every detail. Engines had mostly one or two cylinders, some vertical, others horizontal, some were placed in front, some central and others at the rear of the car. Transmission varied, some used belts on cone pulleys for gear-ratio change, others used gear wheels. Steering devices varied; the majority employed 'tiller' steering, some the cycle-handlebar, and others wheel steering. In three features there was almost universal similarity; in final transmission by the use of roller chain and sprockets; in suspension, by the traditional horse-vehicle springs; and in body design by horse-drawn vehicle-bodies, or that derived from cycle engineering.

In 1895 a few British engineers engaged in experimental work on motor vehicles, amongst whom was J. H. Knight who in that year completed a 3-wheel car driven by an internal combustion engine (using paraffin fuel) which was converted to a 4-wheel car in 1896. The Knight car never reached the manufacturing stage. Amongst the pioneers of 1895–6 were Austin and Lanchester. Mr. Herbert (later Lord) Austin, was contemporary with Lanchester, and both designed their first cars in 1895. The Austin car was a 3-wheel cycle-car having a single driving wheel at the rear and its linked steering wheels in front. It was driven by a 2-cylinder horizontal engine and was somewhat similar to the French Bollée. Later types were also 3-wheel cycle-cars but they differed from their prototype, for the engine drove a 2-wheel back-axle with a single steering wheel in front and a tiller for steering.

To Dr. F. W. Lanchester belongs the credit of designing and building the first British built 4-wheel petrol-driven car, which took the road in March 1896. Lanchester has probably contributed to automobile science more than any other engineer in this country and his earliest

designs incorporated many features that have been adopted in modern cars. They include, among other original devices, live axles; mechanically operated inlet valves; torsionally rigid chassis; compound epicyclic gear; propeller shaft-drive; splined shafts (superseding keys and keyways); pre-selector control; forced lubrication; oil scraper ring on pistons; torsional-vibration damper for the crankshaft; and engine and gearbox as an integral power unit.

Unlike the vast majority of pioneer designers whose work bore the unmistakable imprint of the influence of horse-drawn vehicle tradition, or of pedal-cycle engineering, Lanchester adopted an entirely original view point. He looked on the automobile as a new engineering problem, requiring new technique both in design and in manufacturing devices.

### *Stages of development*

Automobile history falls into three phases or periods: experimental (1895–1904), consolidation of layout (1904–1914), and quantity production (1919–1939). The interval 1914–1919 was more or less stagnant owing to World War I.

In the experimental phase as already said there was no established type. During this period many firms sprang up as manufacturers in this country. For the most part they acquired concessions to manufacture foreign designs, or based their own designs on the more successful foreign types, the majority working on the lines of the Daimler (Germany) or Panhard (France).

The second phase was one of consolidation of ideas, and the automobile began to assume a standardised form, in general layout if not in detail. The most successful features of both British and continental makes were adopted. Belt drives gave place to gearboxes (Panhard); engines were placed in front, as the most accessible position; chain-drive gave place to the propeller-shaft with live axles. With the type established the industry set to work to improve and stabilise details. During this phase ancillary industries—raw materials, foundries, accessory and tyre manufacture—had been developing to keep pace with the requirements of the car builders, and motors developed from single and two cylinders to 4 and 6 cylinders by building up units or pairs of cylinders on a single crankshaft. Foundries were learning to cast blocks of 4 cylinders and later 6 and 8 as monobloc castings.

The third phase (quantity production) was the natural outcome of the second phase, for quantity production is impossible until design is stabilised. America was to the fore in recognising that the essence of cost reduction lay in quantity production, and British manufacturers were not backward in learning to adopt many of their methods in order to compete. But 'mass' production has one serious drawback. It causes

resistance to development, and is a deterrent factor to research, as distinct from testing and production engineering on new models.

It is healthy and inevitable that after a period of progress there should follow a period of consolidation, indeed this is essential to the growth of an industry, but consolidation may continue too long, and it is a serious question whether the automobile industry is not suffering from this disability to-day, and whether it is not time to consider a complete revision of design. Bearing in mind the reliability of the modern power unit there appears to be no vital reason why it should remain in what is now the orthodox position, in front of the car and not at the back. Good visibility and greater road safety would be secured if the driver were to occupy the foremost position in the vehicle. This is recognised in public service passenger-vehicles and many commercial vehicles. The position of the driver of a car can exercise a far greater influence on safety than will any improvement in road planning and construction. The more roads are improved, the faster will the motorist drive up to the limit of safety and that limit in an unforeseen emergency will be exceeded.

It is a lamentable fact that notable inventions of British engineers have passed almost unnoticed by automobile manufacturers in this country, to be subsequently developed in foreign countries and reintroduced to Britain as meritorious improvements in automobile science from abroad. For instance, the four-wheel brake system was devised in this country in 1911, but it was not exploited until about 1922–23 by a Belgian engineer. Independent springing is another example. Lanchester invented the Wishbone Link suspension in 1908, which although devised for aircraft landing-wheel suspension was equally well adapted to road vehicle suspension. This and other independent springing devices were developed and exploited in Germany, Czechoslovakia and America and only then were recognised by manufacturers in this country as desirable improvements. It is difficult to assign precise reasons for this attitude of which there is evidence in other industries. It is in part attributable to the reluctance of British manufacturers to make changes and to the fact that these inventions were before their time. The essential need for four-wheel braking was less apparent at the date of their original invention, since high road-speed was the exception and traffic was far less dense than it became in the 1920's. Independent springing came into its own by reason of (*a*) the introduction of braking on front wheels, (*b*) the adoption of low-pressure tyres, and (*c*) flexible rubber engine mounting which deprived the chassis frame of the torsional stiffness derived from the engine. These improvements lowered the frequency of the bouncing period and brought into importance the gyroscopic forces of the front wheels. It was some time before manufacturers realised that the trouble

due to angular movement of the axle could only be eliminated by causing the front wheels to bounce vertically.

One of the most striking developments in the modern automobile is the high power obtainable from engines of small dimensions. This is primarily due to the great increase in piston velocity which in turn is a result of research and improvement in raw materials, e.g., light alloys used for pistons, high tensile steel for connecting rods, combining to allow of higher piston speeds by reduction of inertia, and the use of high grade alloy cast-iron for cylinder liners, together with improved bearing materials. Moreover, better systems of lubrication effected a reduction in wear and tear.

The rating for tax purposes of motors was based on a piston speed of 1,000 ft. per minute. This was normal in 1903 but today a piston speed of 2,500 is normal and a speed of over 3,000 ft. per minute is not unusual. It may be fairly stated that the taxation rating factor has been the stimulus to a development in which Britain is second to none.

As part of the British trend to use small high-speed engines as compared with the American preference for slow-speed engines of larger size, British manufacturers have led the way in the development of the small car. This has been the direct consequence of two controlling factors, fuel cost and taxation, both penalising the large car with its relatively high fuel consumption. In the U.S.A. it is only recently that fuel economy has assumed a position of real importance in car operation. It is interesting to note the tendency there to follow the practice in this country and develop a smaller and lighter car, helped by their extension of concrete roads. The small car can only become popular in a country with a road system of smooth surfaces, free from dust and mud. Hence it is not suitable as yet for India, the Colonies and large parts of the Dominions.

But the development of the small car with its high-speed engine and a long piston stroke due to the double influence of the high cost of fuel and the incidence of taxation based on the diameter of the cylinder has undoubtedly hampered the export trade in motor cars. The industry has therefore welcomed the recent announcement by the Chancellor of the Exchequer of his intention to alter the taxation to one based on the cubic capacity of the cylinder. If to this concession a reduction of the rate of tax and a smaller number of steps in the grouping of the cubic contents could be added, the manufacturers could reduce the number of models produced and, with a somewhat larger and more flexible engine, compete more successfully in the export market.

Although the industry is barely fifty years old, great improvements have been made in the efficiency of motors through research and development. No account of the development of the motor vehicle and its

engine in this country would be complete without reference to the work of H. R. Ricardo. His investigation of the process of combustion in the cylinder and his study of all aspects of the performance of the high-speed internal combustion engine converted much of the work of the engine designer from a purely empirical process to the scientific application of well-established data. Much remains to be done before all engine and vehicle problems can be solved but Ricardo's work has been an inspiration and guide to many in this field.

*Accessory developments*

Improvements in car performance have not all been due to engineers. The rubber manufacturers have done much. The introduction of the balloon tyre and its perfection have had profound effects, and the safe maximum speed of road travel would probably be no more than half its present rate without the modern tyre. Important advances have been made also in the metallurgical industries; special alloys have been developed to meet the particular needs of the automobile engineer.

*Co-operative research*

Among the earlier formed Research Associations were the Motor Research Association and the Motor Cycle Research Association. Neither was successful in obtaining wide support from the industry and, after some years, the Institution of Automobile Engineers formed a Research Committee with larger industrial support. Co-operative research was conducted by this Research Committee which took over the assets of the previously formed Research Associations. Although not a Research Association with an instrument of government like those of the other co-operative bodies, the Research Committee of the Institution operates in a similar way and has succeeded where the previous Research Associations failed. As an instance of its many successes, the investigation of one of the main causes of cylinder wear in motor-car engines may be cited. It was demonstrated that corrosion by acids formed by combustion could, under certain conditions, greatly accelerate the rate of wear in the cylinders. A comprehensive investigation showed the effects of a large number of engine operating conditions on the rate of cylinder wear and the detrimental effects of cold-running were established. This work has led to a number of important developments by engine manufacturers, such as the use of thermostatic control of the cooling water for rapid warming-up, and the development and application of special corrosion-resistant materials for the parts affected. A very great improvement in the life of engine cylinders has resulted from this work, which is an excellent example of the kind of problem in which co-operative research can assist.

Recent efforts have been made to place the work of the Research Committee on a larger and more adequate footing and it is much to be hoped that a radical change in its scale of operations will soon be possible.

The industry is a rapidly expanding one as the following brief statistics indicate.

| *Output for sale* | *1924* | *1930* | *1935* |
|---|---|---|---|
| Private cars and taxicabs - | 108,311 | 160,321 | 327,152 |
| Commercial vehicles - - | 25,062 | 40,253 | 50,409 |
| Motor cycles - - - | 120,092 | 125,030 | 64,690 |

The greatly increased availability of small passenger motor-cars at a reasonable cost no doubt accounts for the fall in output of motor-cycles. In 1938 licences for mechanically propelled vehicles amounted to about 3 millions.

The rapid increase of public road transport for both passengers and goods is part of the story of services for the community, dealt with on p. 231.

# CHAPTER 4
# BOOTS AND SHOES

*Historical*

Protection for the foot is a human necessity and the craft of making boots and shoes has been widespread throughout this country since mediaeval times. The Cordwainers, so called from the fact that leather was imported from Cordova in Spain to be made into footgear, had a flourishing guild. Various wars in which this country became engaged during the 17th, 18th and 19th centuries gave a great impetus to the craft and centres of production sprang up in different parts of the country to meet the needs of the troops. During this period the industry was essentially a handicraft employing large numbers of skilled operatives.

The Civil War in America also brought about a large demand in that country for boots for the troops and started the production of machinery to replace the relatively slow process of handwork. The original idea of machine sewing was not American, for Thomas Saint secured a patent in this country in 1790 to that end; but the subsequent developments of sewing and lasting machines have been almost entirely American and the result of great ingenuity and costly engineering research and development in that country.

*Boot and shoe machinery*

The position in America, indeed in the world, in regard to boot and shoe production was profoundly influenced by the formation in 1899 of the United Shoe Machinery Company of New Jersey which dominates not only the industry in the States, but also in this country, for the ordinary stock of the British United Shoe Manufacturing Company is held in the States and the voting power is carried by that stock. The formation of the British company was brought about by the need of shoe-making firms to make their products by machinery and to import machines instead of importing shoes produced at a price at which the bespoke article could not compete in the general market.

The arrangements made by this British manufacturing company call for examination because the monopolistic position it occupies affects profoundly the question of research for boot and shoe manufacture.

The machines, covering all the stages of manufacture, are admirable and are the hard-won result of much expenditure and research work, but they are put at the disposal of shoe-making firms on very stringent

conditions. Prior to 1907, if the machines were leased (they have never been sold), no other type of machine could be introduced into a factory: if such were acquired the leased plant could be removed summarily by the lessor. Under a Bill which subsequently became the Patent Act of 1907 all 'tying' clauses in leases for shoe machinery were to be illegal, but the intention of the measure was largely made nugatory by the introduction of a clause, during the passage of the Bill in the Lords, which barred these clauses in machinery leases, except where at the time the lease was granted the lessee had been given an option of taking a free lease on reasonable terms, *i.e.* a lease free from the restrictive conditions. The lessee is not allowed to dispute the reasonableness of the free lease unless he first agrees to accept the tying lease and thereafter seeks redress from the Court. Further the tying lease is drawn in such a way that the lessee admits the offer of a free and unrestricted option of a free lease on reasonable terms. If the lessee subsequently makes a successful appeal to the Court he may have his lease terminated and his machinery removed.

The position was examined in 1917 by a committee appointed by the Board of Trade, which found at that date that practically 80 per cent of British boot manufacturers were clients of the machinery company which adopted as its trade system the leasing of machines at a royalty by means of contracts which years of experience had enabled them to develop to the highest state of stringency. The hirer pays for each machine a monthly rent, and sometimes in addition a royalty based on the use made of the machine. When the lease terminates, the lessee is liable to pay, as 'deferred rent', a lump sum which may be equal to the original cost of the machine. If he renews the lease, the deferred rent is usually foregone and the liability carried forward into the new contract. By this method the company practically ensures the renewal of the lease in perpetuity. The committee pointed out that the manufacturer, who most frequently starts in a small way, is thus tied hand and foot to the machinery company throughout his business life.

This system enables anyone with a small capital who knows nothing about making boots and shoes to set himself up and be taught his trade by the company who not only provide him with first-class machines on hire but service them for him.

*The monopoly position*

The committee of the Board of Trade recommended that agreements restraining the liberty of an individual to buy or use machines of other makers should be declared illegal, and any attempt by promise of bonus or imposition of penalty to arrive at such a monopoly should equally be illegal. Very recently (April 1944) another committee has been appointed

to consider and report whether any, and if so what, changes are desirable in the Patents and Designs Acts, and to give early consideration to 'the provisions of these Acts for the prevention of the abuse of monopoly rights'. No doubt this committee will view afresh this question of boot and shoe machinery leases; for while the existing monopoly has undoubtedly helped small boot and shoe manufacturers and the added cost per pair of shoes has been computed as representing only the small sum of 1½d., a position is created which fetters the industry and destroys its initiative. Owing to the monopoly new British inventions for the industry outside have been few; and inventive minds have turned elsewhere.

To break these fetters will involve large expenditure and much enterprise. It may be that means other than sewing the sole to the upper may be devised which would displace the machinery so widely used. Or some other radical departure from existing practice may be discovered. In any case, the boot and shoe industry of this country has a large task in front of it before it can be independent. It will need to interest itself in the engineering aspects of the manufacture and to become more closely allied to the makers of machines. In the past manufacturers have been content to take the machines leased to them and have not been associated with the development of new types.

*Co-operative research*

A beginning was made in applying scientific knowledge to boot and shoe manufacture in this country by the formation in 1919 of the British Boot, Shoe and Allied Trades Research Association. Starting as a co-operative organisation in Northampton, for long years one of the main centres of the industry, it moved later to London and became a national endeavour in which the other large centres of production joined. It is still on far too slender a financial basis to render the help needed. Its total income from industrial subscriptions and State aid only amounted to £8,150 in 1939. With resources of this order the Association is in no position to assist the industry to bring about the change that is required and to embark on investigations which by their nature are certain to be costly. A radical alteration of scale is needed if the Association is to function effectively. As yet only a beginning has been made. Some of the investigations of a long range nature set on foot by the Association have a statistical basis, e.g., an important investigation on occupational footwear had been organised with the active interest of the Industrial Health Research Board but the work was interrupted by the war. The fatigue, and consequently the health, of employees in occupations requiring many hours of standing is governed to a considerable extent by the way their feet are shod. Arrangements have accordingly included

the issue of large numbers of shoes of types likely to be satisfactory to workers in large factories. These statistical investigations when completed should lead to the production of footwear especially designed to minimise fatigue.

*Size of industry*

The industry is essentially one catering for the home market and it is interesting to note the production figures and those for export, together with the proportion of the latter to the former.

| | *Production (thousand dozen pairs)* | *Exports (thousand dozen pairs)* | *Proportion Exported* |
|---|---|---|---|
| 1907 | 8,120 | 787 | 9·7 per cent |
| 1924 | 7,257 | 998 | 13·8 ,, |
| 1930 | 7,827 | 897 | 11·5 ,, |
| 1935 | 9,009 | 376 | 4·2 ,, |

A statistical study of feet in various possible export markets might lead to the formation of a growing export trade to cater specially for the types of footwear required in countries increasingly making use of foot protection. Large exports to our Dominions were lost during World War I, due in part to the facilities afforded by leased machinery in these countries.

Prior to World War II certain scientifically progressive shoe manufacturers from the continent established themselves in this country and this fact is a further indication that the home industry has need to devote much more attention to the use of science in the trade, if it is to retain the present high percentage (well over 95 per cent) of the home market. While the figures of total production quoted show a notable growth in the industry during the period 1907–1935, there has been a distinct fall in recent years.

The industry naturally thrives in times of war when prodigious quantities of footgear are required by the troops. World Wars I and II brought evanescent well-being to the industry but a very different position will arise under peace conditions. Not only must the home market be retained but efforts made to recapture and extend our export markets. For this purpose the industry would do well to place its research organisation in the position to compete with a very powerful and very efficient organisation that has vast knowledge and experience behind it. Even if fetters are removed by new legislation, the limbs released must be given a restored circulation.

# CHAPTER 5
# CHEMICAL INDUSTRIES

There are few productive industries which are not to a greater or less extent dependent on a knowledge of chemistry for their effective operation on the scientific and technical sides. Several are based essentially on chemistry such as the plastics industry, some like the rayon, paint and photographic industries are largely so dependent, while others have recourse to chemistry for many of their products. In other sections of this Part of the book such specialised aspects of the chemical industry are described in outline. But dyestuffs, alkalis and acids, synthetic nitrogen and explosives represent the heart of the productive chemical industry in this country. These are dealt with below.

As in the case of the electrical industry, science plays an all-important part in the chemical industry, and research and development are essential features in the operations of the firms engaged in it. In illustration of the importance attached to the constant prosecution of research and development it may be recorded that the largest industrial corporation in the country—Imperial Chemical Industries Ltd.—expended in 1938–39 a sum of 1·38 millions sterling on research and development, and that figure may be compared with the combined net expenditure of 0·96 million by the Government on the Department of Scientific and Industrial Research, the Medical Research Council and the Agricultural Research Council in the same year. For the year 1943 the first-named figure had grown to 2·2 millions, in addition to the considerable sums spent for the same purpose by other firms in the industry.

*Dyestuffs*

Prior to the middle of the 19th century dyes were provided by vegetable growths and of these only logwood remains as of importance. Synthetic dyes owe their origin to W. H. Perkin who in 1856 made aniline purple during a quest for synthetic quinine. Perkin was no academic recluse and left the Royal College of Chemistry and his position on A. W. Hofmann's research staff there to set up with his father's financial assistance a dye-works at Greenford Green. He was 21 years of age at the time. He retired from commercial life, a rich man, at the age of 36. While a British scientist was responsible for the discovery of the first synthetic dyes and took a prominent part in their early commercial exploitation, it was left to other countries, and notably Germany, to make full use of the new knowledge. Had Perkin remained in industry and used the financial means accruing from his

early success for further expansion, this country rather than Germany might have led not only in the development of dyestuffs but in organic chemistry generally. Things were industrially over-comfortable here in the latter part of the 19th century.

The essential basic materials derived from coal tar, benzene, naphthalene, and anthracene were fully explored in Germany and a range of different dyestuffs running into over a thousand were made to such an extent and of such quality and cheapness that on the outbreak of World War I that country practically controlled the world production of synthetic dyes. Indigo was an important vegetable dye produced synthetically by German chemists and gradually the whole range of colours needed by the textile industries were manufactured in Germany as a result of research by eminent chemists such as Griess (working in England), Böttiger, Duisberg, Nietzki, Baeyer and Heumann. This country could not dye satisfactorily the khaki uniforms of its troops on the outbreak of World War I and the first makeshift efforts resulted in khaki resembling somewhat the camouflage uniforms of the airborne troops of World War II. It was a crude reminder of the extent to which Great Britain had failed to make use of its opportunities and of the fact that Germany had so established itself in the field of organic chemistry that all other countries looked to it for basic knowledge as well as for the industrial products arising from it. The Government hastily took steps in the matter and brought about the formation of a new company, British Dyes, Ltd.; this afterwards became British Dyestuffs Corporation by the merging of Levinstein, Ltd. and had a capital of £10,000,000 of which the Government held £1,700,000. The result has been to recapture an industry of vital importance to other, and notably the textile industries. Moreover encouragement was given to the prosecution of research in organic chemistry of still wider significance.

The process of making up for lost time called for a fine and tempered ability to learn well and quickly from mistakes and to use to the utmost the recorded results in literature and patent specifications on which to build and make new advances.

At that date the latest range of dyestuffs were those known as vat dyes which owed their importance to their fastness to light. The range starting with blues gradually extended to the full palette but with a notable exception of a bright green. The gap was filled by the discovery in 1921 of Caledon* Jade Green by a number of scientific workers led by Dr. J. Thomas and this dye has been the most important vat green ever since.

* So named from the fact that the discovery was made at Scottish Dyes Ltd. The word has no connexion with *celadon*, the name given to an important series of early Chinese porcelains with a green glaze.

Another development during the inter-war period in this recreated British industry was the discovery of the 'Duranol' dyes, in 1923, by Baddiley and Shepherdson, which are of great importance for the dyeing of acetate silk. Different textile fibres have natural affinities for varying types of dyestuffs. Thus wool has a natural appetite for acid dyes: cotton on the other hand needs a dye with a different chemical structure and may require a mordant to fix the dye on the fibre. Unless these affinities exist the dye would disappear on the first washing. In the case of acetate silk there was little affinity for any of the known dyestuffs and no mordant to act as an intermediary. The Duranol dyes (based on certain amino anthraquinones) made possible the dyeing of this important rayon fibre in fast bright and deep shades.

A third important British discovery was that of the phthalocyanines, distinguished by exceptional properties of fastness and chemical inertness. Monastral blue is the type example. The discovery of a new chromophore resulted which has approximate chemical relationship with the green colouring matter of plants (chlorophyll) and with the red colouring matter of animal blood (hæmoglobin). The discovery of phthalocyanine was not only an achievement of industrial importance but an extension of knowledge in organic chemistry. As a rule industrial research follows advances in knowledge of a purely scientific kind: in this case industrial research led the way and the new information marched straight into the text books.

The foregoing examples of British dyestuffs discoveries show that this country has not merely re-established the industry in an imitative way but to an important degree has extended its range by creating new and novel products. It has also become one of the leaders and not a follower in the field of organic chemistry. The number of organic chemists in the country has risen during the last thirty years from a mere handful to thousands.

Another interesting development may be mentioned. A not unimportant discovery of recent date (1936) in this country is that of Velan with its property of making cotton, silk, and to some extent wool, resistant to water. Previously water repellency had been brought about by coating textile fibres with rubber or by impregnation with emulsions of paraffin wax, but these took away in varying degrees some of the desirable properties of the textile materials. Velan overcomes the difficulty and renders the material resistant to ordinary washing and cleansing processes as well as making it showerproof. It has proved of much interest in the United States where it is known as Zelan.

*Alkalis, acids and related chemicals*

The so-called heavy chemical industry comprises the manufacture

of alkalis such as soda ash and caustic soda; acids such as sulphuric acid, hydrochloric acid and nitric acid; chlorine, bleaching powder, sodium sulphide, etc. It has behind it a long history of industrial research and this is not surprising, for while many industries are based on a craft and have been modified to industrial needs by the application of power, the industry is based originally upon chemical discovery. Until the close of the 18th century no chemical industry in the proper sense existed for there was not previously a sufficient demand for manufactured chemicals. At this period it became possible and practicable to smelt iron ore with coal and to produce power from the same source by means of the steam engine: these two factors led to the beginnings of a great textile industry and so to the need for chemicals. For many years the technical problems involved in the mere production of these chemicals was the sole occupation of their manufacturers, and at that date the chemical industry was a bad and smelly neighbour. W. Gossage, who first introduced a tower packed with small pieces of coke over which a stream of water was allowed to flow, made the earliest contribution to the solution of the atmospheric pollution problem. This technique was developed to deal with other destructive waste gases to comply with the Alkali Act of 1863. But it is important to remember that had this measure been enacted much earlier the chemical industry might well, for lack of the means to comply with the provisions of the statute, have been abandoned. Technology had not advanced far enough; the chemicals employed in the chemical and allied industries are inherently reactive substances, and by their very nature display their corrosive and active properties during the course of manufacture, as well as in their subsequent use.

The ammonia-soda process seems to have been discovered by Fresnel in France in 1810. The particular industrial process in use at the time was known as the 'Black Ash' process. In simple terms, it consisted in heating common salt with sulphuric acid and roasting the resulting sodium sulphate with chalk and coal. The mass was extracted with water and the sodium carbonate crystallised out.

The Solvay process evolved in the latter half of the 19th century from Fresnel's discovery was much more elegant and had the aspect of being fundamentally a cheaper one. It was, in bare essentials, a treatment of a solution of common salt with ammonia, and subsequently blowing in carbon dioxide gas so as to form bicarbonate of soda and ammonium chloride. The ammonium chloride was decomposed by lime into ammonia gas which could be used again in the first stage. The bicarbonate of soda was in turn decomposed by heat into sodium carbonate and the carbon dioxide evolved used in the first cycle of operations.

As some indication of the difficulties which confronted the early

alkali manufacturers and indeed of all development processes the following extract taken from Miall's *History of the British Chemical Industry* is interesting: 'In 1836, Thom tried the process at Camlachie, in Scotland, but lost money and he dropped it. In 1838, Dyer and Hemming took out a patent for an improved method of working the process; they tried it for a couple of years, lost money over it and abandoned it. About 1842, Seybel tried it at Liesing, near Vienna; again it was unsuccessful. About 1854, Bowker tried it at Leeds; again it was not a success. In 1854, Gaskell, Deacon & Co. tried a similar process, and failed to make it pay. In 1858, Schloesing and Rolland tried it at their works near Paris; after a considerable pecuniary sacrifice the works had to be closed down.'

'Solvay in Belgium, in 1856, and Brunner Mond in England, in 1873, started the process and it grew and still remains the world over the chosen process for the production of soda ash. From that time to the present day an immense amount of scientific and technological skill and research has been lavished on this process. It is probably the most utterly refined chemical process there is. Yet, as Ludwig Mond tells us, in the first months "everything that could break down did break down; everything that could burst did burst".' On a new discovery being made the chemical industry has not only to resolve and define the pure chemical problems involved but to translate them into a practical technology. The period of gestation between conception and practical realisation refuses to be shortened no matter what resources are deployed to the purpose.

The displacement of the Black Ash process for sodium carbonate by the Solvay process is an example of how over a period of time on economic grounds, one process survives and another falls into disuse. But examples can be quoted where two different processes for an identical product prosper side by side. Caustic soda, for instance, can be produced from soda ash by reaction with lime; or it can be produced directly from salt by electrolysis. The cost of power is a very considerable economic factor in electrolytic processes and much research has been necessary on this aspect of chemical industry.

### *Sulphuric acid*

Sulphuric acid may be produced either by the 'chamber' process or the catalytic process, and both are in use today. Sulphuric acid was originally made by heating alum, green vitriol and other sulphates and condensing the products of distillation to form 'Nordhausen sulphuric acid'—so named from the town in Germany in which it was made for many years. Sulphuric acid or the combination of sulphur trioxide with water is produced by the formation of sulphur dioxide (from the

burning of sulphur in air or roasting sulphides of iron or zinc) and its conversion into the trioxide by oxygen (either from nitrous oxide in the 'chamber' process, or from air and a catalyst* in the contact process).

The commercial production was advanced by Gay-Lussac in 1827 who found a way of conserving the nitrous fumes carried away from the lead chambers in which the reaction took place by bringing them into contact with moderately strong sulphuric acid already formed. This discovery was elaborated by Glover in 1866. The whole process briefly consists in passing the sulphur dioxide obtained from burning pyrites or elemental sulphur together with air through 'Glover towers' packed with acid-proof stone or brick over which acid from the Gay-Lussac tower and from the lead chambers trickles down. The gases pass on to the large lead chambers where they meet more nitrous vapours and 'chamber acid' is formed. The excess gases are passed through the Gay-Lussac tower, which is similar to the Glover tower but packed with coke over which stronger sulphuric acid trickles. The process is consequently a continuous one, the products of one stage being used for another and conservation of nitrous vapours secured.

The catalytic process differs in that sulphur dioxide gas is passed along with air over a catalyst when the two gases unite to form sulphur trioxide. Platinum (or vanadium) is used as the catalyst and is deposited on a suitable substratum so as to facilitate the contact with the gases in their passage over the catalyst. Much patient and accurate research had to be carried out before the catalyst had any useful economic life. It was found that certain impurities poisoned the catalyst, notably arsenic and chlorine, and that even minute amounts of these carried forward as a mist in the gases were sufficient to upset the working of the plant. Indeed, the gases must be so free from mist and suspended particles that the passage of a beam of light projected in the gas stream should not be visible to the eye.

There were in 1885 about 50 chemical firms with works in Glasgow, Newcastle, St. Helens, and other places, and about 45 of these were grouped together in an entity known as the United Alkali Company. In 1927 Imperial Chemical Industries, Limited, was formed through the merging of Brunner Mond & Co., Nobel Explosives, Ltd., British Dyestuffs Corporation, Ltd., and the United Alkali Company. This very large corporation is the outstanding instance of the growth of the industrial unit in the chemical industry and has been brought about in large measure by the need for organised research on an ever-increasing scale.

* The function of a catalyst was compared by the late Sir William Bragg with that of a chaperone at a Victorian ball, who, having introduced the partners, retires while they dance.

*Synthetic nitrogen*

Another branch of the chemical industry which received a new impetus as a result of the lessons of World War I was the production of fixed nitrogen. During that war the difficulty of obtaining supplies of nitrate from Chile in sufficient quantities became almost insuperable and the Government erected a plant on the Haber-Bosch principle. Haber, a Jew, was one of the men who helped Germany create its great chemical industry and was the first to conduct successful work on the fixation of atmospheric nitrogen. At the close of the war the Government decided, as in the case of British Dyestuffs Corporation, to encourage private enterprise to take on the business. As a result Messrs. Brunner Mond and their subsidiary, Synthetic Ammonia & Nitrates, attacked the problem which at that date was far from being solved on a commercial basis.

At Billingham, near Stockton-on-Tees, the necessary equipment was erected for the high-pressure technique required. Here a synthetic ammonia plant beginning with water-gas and ending up with ammonium sulphate was erected. While this work was going on, a plant to make 2 tons of ammonia a day was erected by Messrs. Castner-Kellner where considerable quantities of hydrogen, made as a by-product in the caustic and chlorine industry, were available. As a result of these initial steps a complete plant at Billingham for the manufacture of 250 tons of ammonium sulphate a day came into operation in 1923. By this means using anhydrous sulphate of lime obtained locally to fix the ammonia, independence of imported sulphur or sulphur compounds is secured and a whole range of compound fertilizers is available from indigenous sources and without foreign assistance.

Two further extensions of the chemical industry arose out of the synthetic nitrogen industry. First, the production of nitric acid by the direct oxidation of ammonia instead of the now obsolete process of decomposing sodium nitrate with sulphuric acid. The great importance of this development is shown by a comparison between the needs of the explosives industry in World Wars I and II. In 1914–1918 all the nitric acid used was made from nitrate carried by ships from Chile. During World War II it has been all produced from synthetic ammonia. Had this not been the case the extra burden on shipping might have been critical.

The second extension arose out of the new technique of high pressure reactions. In the synthesis of methyl alcohol (methanol) from carbon monoxide and hydrogen the chemical industry added another product to the list of synthetic products which have replaced the so-called natural products. Methyl alcohol, a product of wood distillation, is one of the principal raw materials in the production of phenol formaldehyde and

urea formaldehyde resins which are referred to on p. 127. Shortly before World War II, another development arose out of this same technique of high pressure reaction in the production of petrol by hydrogenation of coal, and this is dealt with on p. 37.

*Explosives*

While naturally explosives are essential for military purposes, they are of great industrial importance. Blasting operations in coal and metalliferous mines and in stone quarries depend upon them. Railway tunnels and cuttings and other engineering operations also call for their use. Shot-firing in coal mines has been touched on elsewhere (p. 31) from a safety point of view and here will be traced some of the major landmarks of the evolution of explosives for industrial purposes with only incidental reference to military explosives.

*Gunpowder*. Gunpowder appears to have been first discovered in China or imported there from India in the 5th century. It was used for firearms in China in the middle of the 12th century. In the same century it appears to have been used by the Moors in Europe, and it continued to be the explosive of the world until the middle of the 19th century. Explosives depend for their effect on the unstable condition of their constituents which on ignition or detonation assume more stable forms. Gases are evolved and the power factor depends on their volume, the rapidity of their evolution and the heat produced. Gunpowder is a 'low' explosive since the chemical changes that take place in the mechanical mixture of potassium nitrate, sulphur and charcoal proceed from particle to particle. The potassium nitrate (70–75 per cent of the whole) takes no direct part in the chemical reaction and only serves to oxidise the sulphur and charcoal into their oxides. The newer explosives described below are 'high' explosives and in their case all (or practically all) the constituents are converted into gas.

The safer use of gunpowder for industrial purposes was greatly advanced by the Bickford fuse. William Bickford, a native of Cornwall, invented a method of wrapping a cylinder of compressed gunpowder with twine and subsequently immersing it in varnish. In this way the charge could be exploded from a distance by firing the fuse which was also impervious to moisture and could be used under water.

*High explosives*. Fulminate of mercury was discovered by Howard, an Englishman, in 1799; but the chief high explosives were discovered on the continent. Nitroglycerine was first made by Sobrero (Italy) in 1846; nitrocellulose by Schönbein (Germany) in 1845. It was, however, a Swede, Alfred Nobel, who developed their use and who may be regarded as the father of modern explosives. He discovered (1866) dynamite by absorbing nitroglycerine in infusorial earth and so providing a

readily portable explosive. It was also Nobel who found that he could dissolve dinitrocellulose in nitroglycerine to form a gelatinous colloidal mass that could be moulded to any desired form or cut into strips. This smokeless explosive, called by Nobel 'ballistite' is the progenitor of all smokeless propellents of which cordite is well known in this country. Though fulminate of mercury had been used for percussion caps for many years, Nobel also discovered a way of using it for making effective detonators for high explosives.

In addition to the nitroglycerine explosives a number of others have been evolved with the object of increasing the safety factor in their manipulation. They are composed of nitrates and chlorates with combustible nitro bodies such as trinitrotoluene (T.N.T.). The name 'Ammon' is used to signify the class of industrial explosive in which a portion of the nitrogylcerine has been replaced by ammonium nitrate and this group has been considerably developed.

The 'sheathing' of explosives for shot firing in coal mines is referred to on p. 29. Its practical use was developed by Lemaire (Belgium). The object is to enclose the explosive in a sheath of cooling material and so prevent ignition of fire-damp. The sheath used now is made of sodium bicarbonate made up with wood pulp into a felt.

It is worth noting that South Africa is an important producer of high explosives which are required for use in its important metalliferous mines, gold and copper in particular. The production in 1938 of explosives in South Africa was about three times that of the United Kingdom. The production in the United States was more than ten times that of this country.

CHAPTER 6

# COAL: ITS WINNING AND UTILISATION

## *Output and general uses*

The coal measures of this country are its most valuable mineral possession and the industrial supremacy attained by Great Britain in the 19th century was largely based on the lead we gained over other countries by exploiting them. One of the first uses made of coal in any large quantity was for heating buildings and to that end more than a quarter of the total coal output in Great Britain is employed today. Coal for steam raising to drive the machinery of the Industrial Revolution was one of the next major calls on the supply and about one-third of the coal raised at present is used to generate steam for various purposes, including the generation of electricity. About one-fifth of the coal output is carbonised and approximately half the coke and a proportion of the gas produced is used for metallurgical purposes.

The fluctuation in coal output during the fifty years prior to World War II is shown in the following table:

| | | | |
|---|---|---|---|
| *1886* | 157 million tons | *1920* | 230 million tons |
| *1890* | 181 ,, ,, | *1924* | 267 ,, ,, |
| *1900* | 225 ,, ,, | *1930* | 244 ,, ,, |
| *1913* | 287 ,, ,, | *1938* | 227 ,, ,, |

During World War II the output dropped further; the figure for 1943 was 194·5 million tons and in 1944 184 million.

The consumption of coal among some of the main industries and utilities according to the Census of Production made in 1935, was as follows:

| | *Million tons* | | *Million tons* |
|---|---|---|---|
| Iron and steel - - - - | 8 (with an equal tonnage of coke) | Gas works - - - | 18 |
| Clay and building materials - | 8·6 | Electrical generating stations - - - | 12 |
| Textiles - - - - - | 7·6 | Railways - - - | 12 |
| Chemicals - - - - - | 4·1 | Collieries - - - | 12 |
| Paper-making - - - | 3·1 | Coke-ovens - - - | 17 |
| Engineering, ships and vehicles | 1·6 | Domestic - - - | 40 |

## *Early winning of coal*

Great Britain has been the pioneer in research into both the winning

and the utilisation of coal. The basic methods of coal mining—the pillar and stall and long-wall systems—were evolved in this country. We have also in Sir Humphry Davy the hero of the fight against the fire-damp hazard by his invention of the safety lamp. Benjamin Thompson (Count Rumford), when he framed the original prospectus of the Royal Institution, announced that the better use of coal for domestic purposes would be studied. His contemporary, Murdoch, gave the gas industry to the world. The coal-fired locomotive was a British invention.

The lay-out of British coal mining improved steadily through the 19th century. Thus, in the mid-19th century, ponies replaced man-handling underground and steam traction was adopted on the surface. Later, underground conveyor belts greatly increased the rate of output. Much of the coal at the face is still cut out by sharp-pointed double-armed picks, but machine cutters, usually worked by compressed air, are increasingly being used where feasible. By 1938 about 60 per cent of the coal raised was being cut by machines and the proportion has since risen to about 70 per cent.

Blasting by explosives placed in 'shot holes' has been employed for a long time. Seventy-five years ago gunpowder was the only explosive used. Nitroglycerine was introduced in 1869, but it was some time before its use was improved sufficiently to make it safe to handle. Various other forms of explosives have since been evolved, until in 1934 there were 45 approved for general use; especially important are certain 'sheathed' explosives to prevent ignition of fire-damp. The 'sheathing' consists of an envelope of sodium bicarbonate. The propping of the coal galleries and their approaches has been the subject of engineering investigations and their lighting has been greatly improved by the latest forms of electrical illumination.

### *Underground gasification*

There is a special aspect of winning coal, or at all events its energy value, that calls for reference, though as yet it has not been explored in this country. The gasification of coal *in situ* was first suggested in 1864 by Sir William Siemens and taken up later by Sir William Ramsay. Since 1913 the possibilities have been examined more fully in Russia. The underlying idea is to produce gas from unmined coal and to convey the gas and other products to the surface for subsequent utilisation. The coal was to be ignited and treated with air or oxygen, steam was to be pumped down to the seam and the resulting gas conveyed up through another shaft. The products could be used either for heat and power or as a source of oils and chemicals. The idea has yet to be proved economically feasible.

### *Coal-getting research*

The winning of coal involves above all else the safety of the men who mine it. Organised research on safety in coal mines on a large scale began in 1908 when the Mining Association of Great Britain voted £10,000 for experiments on coal-dust explosions. These experiments conducted at Altofts in Yorkshire by Sir William Garforth, assisted by the late Dr. Wheeler, proved that coal-dust alone, if raised as a cloud, could cause an explosion under conditions existing in a coal mine. The work was taken over by the Home Office which established at Eskmeals in Cumberland an experimental station to explore the stone-dust remedy and to begin experiments with the object of preventing the ignition of fire-damp.

### *Safety in Mines Research Board*

In 1920 a special committee appointed by the Home Office recommended the establishment of a permanent Research Board. This was carried out in 1921 after the duties of the Home Office in regard to mines were taken over by the Mines Department. The Board, at first a small one, was reconstructed in 1923, and it was laid down by the Secretary for Mines that while the Department retained administrative and financial responsibility, the Board would be completely independent in the direction of scientific research. The Mining Industry Act of 1920 (section 20) specifically mentioned research as one of the purposes of the Miners' Welfare Fund and the supervising committee, in the first statutory period of the Fund, decided to apply approximately half the General Fund to research purposes. For this period the Fund was based on a levy of 1d. per ton of coal raised in each year. In 1926 the levy was reduced to ½d. per ton, but since the last extension of the welfare levy in 1934, the rate has been 1d. per ton. In 1926 the Welfare Committee endowed the work of the Safety in Mines Research Board with approximately £260,000, which now provides an annual income of £12,397, and a sum of £20,000 a year has been statutorily earmarked for research purposes as a prior charge on the fund under the Mining Industry (Welfare) Act, 1934, which also allowed the Miners' Welfare Committee to apply additional grants for this purpose. Annual grants from the Welfare Fund in the immediate pre-war years amounted to about £45,000 per annum, rising to a peak of £48,834 for the year 1939-40. In that year the estimated expenditure for research reached a figure of £60,850 and for safety instruction £3,393.

The work of the Safety in Mines Research Board is mainly carried on in laboratories at Sheffield and in London, in explosion galleries at Buxton and in coal mines in each of the major coal fields. Grants-in-aid are also given for extra-mural researches. At the Sheffield laboratories, experiments are conducted on the stone-dust remedy for coal-

dust explosions, on various means for preventing the ignition of fire-damp and on the properties of the strata of the coal measures. Stone-dust is as yet the best preventive for coal-dust explosions and the experiments are aimed at finding the best stone-dust to use and the best way to use it. To this end the different stone-dusts are being classified and their respective characteristics ascertained before they are tried out in the explosion galleries at Buxton. An explosion of fire-damp is not only dangerous in itself but raises a dense cloud of coal-dust in the mine and unless a sufficient proportion of stone-dust is present, the flame of the fire-damp will cause further explosions. It is therefore imperative to prevent ignition from the appliances used, from the pick striking a spark against a rock to electrical equipment used for lighting, signalling and shot-firing. In both these directions much success has been achieved, but more work is being done for the guidance of manufacturers of electrical equipment. The exploration of potentially dangerous conditions in shot-firing and the improvement of explosives have reduced the number of shot-firing accidents to relatively small proportions. Methods of 'dust proofing' to prevent its explosion by spraying with oil have also been examined by the Fuel Research Station.

Research has also been directed to the reduction of haulage accidents so much more frequent underground than on the surface, due to cramped conditions and lighting insufficient for easy inspection. Suitable designs for tubs, wheels and rails and the best metals for haulage gear have been investigated and protective devices of all kinds examined. Accidents from falls of roof and sides of galleries are being reduced by the scientific study at Sheffield of the underlying causes. This aspect is investigated at the major coal fields and the results collated. Since the outbreak of World War II the Ministry of Fuel and Power has appointed a body of inspectors to see that the results of all these researches are used.

*Co-operative research on mining*

The earliest co-operative research organisation for the industry was local in origin and scope, the Lancashire and Cheshire Coal Research Association, founded in 1923 on the initiative of Mr. (now Sir Robert) Burrows. But the chief agency conducting research on coal getting, apart from the Safety in Mines Research Board, is the British Colliery Owners' Research Association formed in 1924, the funds of which are provided by the Mining Association of Great Britain and by grants from the Safety in Mines Research Board. Much of the early work of the Research Association consisted in support of important researches conducted by the late Professor J. S. Haldane, who not only did work on stone-dusting and on ignition in coal

mines, but investigated the cause of silicosis and the influence of poor lighting on the incidence of nystagmus. As an eminent physiologist he made great contributions to the prevention of these diseases. After his death the work of the Association was transferred from Birmingham in 1937 to the Royal School of Mines of the Imperial College of Science and Technology where it is administered by a joint Committee of the College and the Association. A beginning has also been made in recent years in securing, through the Association, the active co-operation of district committees for the investigation of urgent problems of dust suppression.

In 1937, at the request of the Mining Association, a report on the Organisation of Research for the Coal Industry was prepared after several months' study of the problem in most of the principal coal mining districts of the country and the university departments of mining and associated studies, the laboratories of the Safety in Mines Research Board at Sheffield and those of the Lancashire and Cheshire Coal Research Association in Manchester. The report recommended the establishment of a national Research Association on a federal basis with district research committees appointed by and working in each district or group of districts, and a central co-ordinating council working in close co-operation with the district committees and assisting them financially, and with other research authorities including the universities and colleges having departments of mining and fuel. The council was to include independent men of science and representatives of the universities as well as representatives of the Safety in Mines Research Board, the Fuel Research Board and the Coal Utilisation Council (the forerunner of the British Coal Utilisation Research Association (B.C.U.R.A., see p. 39). To this body the utilisation proposals of the report have since been referred. It would, in the opinion of some able men connected with the industry, have been more satisfactory had both this Association and the British Colliery Owners' Research Association (B.C.O.R.A.) been combined in a single organisation for the industry as a whole. If, as suggested elsewhere (p. 274), certain functions of the Fuel Research Station could be transferred to the enlarged Research Association, so much the better. But in any case it is essential that the three organisations should work in much closer co-operation than hitherto. The report estimated that the initial income required to carry out its various proposals would be about £79,000, which should be met by an annual levy of $\frac{1}{15}$d. on each ton of coal raised, yielding at that time rather more than £60,000, the balance to be obtained from other sources. It was pointed out, however, that the cost of the Association if successful would certainly grow.

The problems of coal winning are complex, involving chemistry,

physics and physiology as well as engineering, and so different are the coal seams, the geological conditions and the commercial circumstances in the coal-bearing regions of the country, that a large measure of decentralisation in the conduct of research is imperative. Larger sums are needed for research and development in the winning of coal and for the dissemination of knowledge acquired here and in other countries. The estimate of the British Colliery Owners' Research Association (B.C.O.R.A.) for the year 1944–45, apart from the work undertaken for the Safety in Mines Research Board, is only about £4,350.

*Research by individual firms*

Apart from the public and co-operative agencies referred to, several large firms are spending considerable sums on research for their own purposes, notably the Powell Duffryn Associated Collieries which have a well-equipped central research department in Glamorganshire and experimental plant elsewhere. The Manchester Collieries and Wigan Coal Corporation representing together 46 per cent of the output of Lancashire are both active in research and development.

*Coal preparation*

After the 'winning' has been accomplished, the coal has to be prepared for the consumer, processes which both scientifically and commercially are the proper function of B.C.O.R.A. Methods of cleaning and washing coal have been the subject of much investigation and consequent improvement. The first mechanical coal-cleaning appliance used in this country was the jig washer, introduced at Newcastle in 1849. Improvements in jig washing made in Germany (Baum of Westphalia) simplified control and reduced the power requirements and so made it possible to build plants of much larger capacity. More recently, attention has been directed to the dry cleaning of coal, the separation of coal from dirt being dependent on the difference between the co-efficients of friction, specific gravity and other physical properties of coal and dirt. These cleaning devices were first applied here in the 1920's. Since 1927 the coal cleaning capacity has been more than doubled in this country, and between 1927 and 1938 the proportion of mechanically cleaned coal has increased from 20 per cent to 45 per cent.

Other methods of cleaning fine coal have been explored, including the 'vacuum flotation' method, the first plant for which—of a commercial size—was erected at the Fuel Research Station to examine the process and to indicate the types of coal best suited to this method of cleaning.

*Utilisation*

The increased quantitites of fine coal and dust brought to the surface by modern methods of winning have accentuated the importance of utilising this material. Pulverised-coal firing is one of the most promising methods and much work on burning powdered coal has been done at the Fuel Research Station. The burning of pulverised coal under Lancashire or marine boilers with their limited combustion space is a problem distinct from the burning of pulverised coal in power station boilers with their large combustion chambers. Various forms of pulverised-fuel burner have been devised and used with success. The use of pulverised coal for internal combustion engines of the Diesel type has also been examined, though in this Germany has been the pioneer. Abrasion by the ash of the coal used is the main difficulty in the way.

The mechanical side of coal utilisation has also received attention in recent years. Mechanical stokers for firing boilers were first introduced a hundred years ago, but only came into general use after World War I. Since then they have been much improved in construction, so that increased combustion efficiencies and improved burning rates are now possible with decreased capital outlays. This country is still far from being as highly mechanised as the U.S.A. where official statistics show that more than one million automatic coal stokers are used in central heating installations alone.

The economic stimulus to these advances was provided in part from the competition arising from the use of pulverised fuels. In 1900 a boiler producing 15,000 lb. of steam per hour was considered a large one, but today units of 200,000 to 300,000 lb. of steam per hour are common in power stations and the ordinary industrial water-tube boiler has a 20,000–100,000 lb. per hour capacity. These higher capacities have been accompanied by increased thermal efficiencies, so that while in 1900 a 60 per cent efficiency was considered excellent, one of 80 to 85 per cent is now normally expected in large plants.

There is, however, still great scope for improvement in smaller industrial boilers. It has been estimated by the Ministry of Fuel and Power that we were using at the outbreak of World War II some 50,000,000 tons of coal for industrial steam raising with an efficiency of less than 55 per cent. An increase of efficiency to the figure of 80 per cent cited above would save the country some 15,000,000 tons of coal a year. This is equivalent to a present capital value of a thousand million sterling.

The domestic grate for burning solid fuel has been the subject of research, and several types, labour-saving in use, smoke-reducing in operation and capable of continuous burning, have been and are being evolved. In these modern grates a considerable reduction in the waste of heat up the chimney is obtained.

*The coal survey*

Owing to the varying characteristics of the coal from the different coal-fields of this country it is of high importance that the prospective consumer should know what type he should buy for his particular purposes. The greatest national service provided by the Fuel Research Station is its Coal Survey, which is conducted from nine laboratories situated in the principal coal-fields and collated at the central Station at Greenwich. More than 50 reports to date have been published, chiefly on systematic examination of the properties of the coal as it occurs in the seams. Many commercial grades have also been examined. In the Yorkshire, Nottinghamshire and Derbyshire coal-fields alone over 1000 samples of different grades of coal of varying classes have been examined, from large hand-picked sizes down to unwashed slacks. From these reports the colliery owner gains knowledge of his seams and of the variations that occur from point to point within a seam; and the consumer can choose the type of coal best suited to his needs. The Survey, while devoting major attention to qualitative studies, is now making quantitative estimates of the reserves of different types of coal, in collaboration with the Geological Survey and the Coal Commission. As a result of the work of the Coal Survey we know more about our coal resources than any other country about its own coals. Such information is of obvious importance in planning to ensure the best use of our coal resources, not only for the home but also for the export market.

*Coal to coke*

The conversion of coal into coke is of much industrial importance; as already noted, the iron and steel industry used 8 million tons of coke in 1935. The coking industry had its origin in the 16th century, when charcoal-smelting of iron was taking a dangerous toll of our timber supplies. Coke has proved a more than worthy substitute for charcoal, but no serious interest was taken in the by-products of coal carbonisation until the middle of the 19th century. In 1907 over 60 per cent of the coal used for making metallurgical coke was carbonised in old-fashioned bee-hive ovens; but by 1933 more than 97 per cent of the metallurgical coke used was being made in by-product recovery ovens of modern design. The coke-oven industry is important and sufficiently large to have justified the recent formation of a separate Research Association to study its scientific problems.

While the production of high-temperature coke continues to be the predominant carbonisation process, developments have been made also in low-temperature coke, a product which can easily be ignited from sticks and paper in the domestic grate. Its use has the enormous advantage of reducing to negligible quantities the emission of smoke. Various

methods of low-temperature carbonisation have been evolved in this country and these have been examined and reported on by the Fuel Research Station. That Station has also developed its own methods which have been adopted in commercial practice, but low-temperature carbonisation is only applicable to coals which have a caking quality and a relatively low ash content.

*Coal to gas*

The close connexion between coke production and the gas industry, with its by-products ammonia, tars and sulphuric acid, makes it more appropriate to deal with these under the note on the gas industry (p. 66). Coal for domestic heating, for steam raising and for the production of coke and gas, while constituting by far the greatest use of this national wealth, by no means exhausts its value. The waste of coal products that occurred in the 19th century in the form of atmospheric pollution and by the neglect of its potentialities for purposes other than heating was prodigious, and it is only in recent years that this country has begun to appreciate the full possibilities of coal as a raw material in the production of materials of greater value; moreover the waste of the past has not only made unnecessary inroads on our mineral wealth but has caused an avoidable and destructive smoke nuisance. It is here that scientific knowledge and research have played, and are playing, an all-important role.

The lines of investigation are numerous and are outlined below with no attempt to put them in order of economic importance. Indeed such appraisement is impossible at the present time.

*Coal to oil*

This country is fortunate in being able to obtain through its shipping ample supplies of petrol for aviation and motor propulsion. Germany, being less fortunately placed, devoted much attention to synthetic petrol from brown coal or lignite of which it possesses large quantities. The importance of the hydrogenation of lignite was recognised in that country and the Bergius process was fostered by succeeding governments. The rights of that invention in this country were acquired by the Government in 1924 on the advice of the Department of Scientific and Industrial Research, and a Bergius plant was erected at the Fuel Research Station in 1926 for the treatment of bituminous coal on a scale of one ton a day. After these early explorations the whole question was taken up exhaustively by Imperial Chemical Industries who erected a large plant to develop the process in this country and devoted much scientific work to its improvement in terms of the coal available. By the hydrogenation of a ton of coal about 160 gallons of motor spirit can

be obtained, but as a further ton of coal is required to produce the necessary power and hydrogen, the net yield is about 80 gallons per ton. Tar and tar oils can also be used as the raw material for hydrogenation. The output from the plant belonging to Imperial Chemical Industries was in 1938 about 42 million gallons.

The process in outline is as follows: the coal cleaned as far as possible from ash is ground and mixed with a pasting oil and a catalyst, and the paste, mixed with hydrogen under a pressure of 250 atmospheres, is heated to the reaction temperature in a gas-fired preheater and passed through a series of converters. On leaving the last converter, the gases and vapours are separated from the residual heavy oil which contains the ash and unconverted coal. The gases and vapours pass to the heat exchangers and coolers; the liquid oils are separated under pressure and the gases, after washing out any excess hydrocarbons, are re-circulated. Part of the heavy oil from the hot separators is returned to the paste preparation plant and part to the sludge-recovery plant where it is converted into coke for burning under the boilers and into oil for making paste. The light oil products from the cold separators are released under pressure in three stages. Part of the heavy oil is treated in a second liquid-phase stage and then, after separation of the liquid-phase petrol, the middle oil in the product is treated in a final vapour-phase stage. The vapour-phase petrol requires no refining after washing with soda; the liquid-phase is washed with sulphuric acid, then with aqueous caustic soda and finally re-run.

The Fischer-Tropsch process for the synthesis of hydrocarbons from carbon monoxide and hydrogen was invented in Germany in 1925 and investigated by the Fuel Research Station in 1934. The efficiency of the process is much the same as that of the Bergius process so far as the production of oil is concerned, about 1 ton of oil being obtained from 4 or 5 tons of coal (including that required for heat and power during the process). The main products obtainable include Diesel oil, motor spirit and wax. Some of the products serve as raw materials for the production of soaps and fats, and the process has other potentialities. The process is not very suitable for motor spirit, as the low-boiling fractions have very poor 'anti-knock' properties and must be 'cracked' or 're-formed'. The Diesel oil obtained is of high quality.

### *Producer-gas*

Until the outbreak of World War II the question of an alternative to petrol as a fuel for road traction was unimportant, but the necessity for petrol economy at that date threw into fairly high relief the desirability of being able to drive a motor vehicle by other means. Producer-gas engines for road transport were intensively examined and several

methods of using anthracite, low-temperature coke and high-temperature coke were investigated together with their attendant problems. Fairly satisfactory results were obtained, but it would not appear likely that this mode of propulsion will be developed for general use unless the world supply of motor spirit, natural and synthetic, shows signs of failing. The somewhat bulky equipment necessary as accessories to the vehicle prevent its adoption except under economic compulsion.

*Coal by-products*

The by-products from coal in its conversion to high temperature coke provide many major industries with their essential basic materials. First and foremost is the dyestuffs industry, which has, since its inception, depended on coal tar. The plastics industry, and other sections of the chemical industry, not to mention the rubber and paint industries, are all dependent to a greater or less extent on the products of coal carbonisation. The high value and wide range of the chemical by-products of coal carbonisation became more generally recognised during World War I. During that period the production of phenol to make picric acid and toluene for high explosives such as T.N.T. or trinitrotoluene was undertaken on a very large scale. Coal tar for road dressing has been used for some time, and immediately prior to World War II one-third of the annual production of tar (from gas-works and coke ovens) was so used. The two main products of tar distillation (creosote and pitch) accounted for more than half the coal tar produced. Coal tar contains many different chemicals, of which about two hundred have been isolated. The main substances extracted are benzene, toluene, the xylenes, phenol, the cresols, naphthalene, anthracene and the pyridine bases. The light aromatic hydrocarbons provide solvents, explosives, dyes, saccharine and medicinals; and many of the synthetic resins, including some types of synthetic rubber, are derived from them. Phenol and the cresols find uses in preservatives, antiseptics, dyes, drugs and perfumes, whilst the thermo-setting plastics are mainly based upon them. Fumigants and insecticides are derived from naphthalene, which is also required for the preparation of phthalic anhydride for another branch of plastic materials. A potential but as yet little developed derivative from coal is acetylene, one of the most important raw materials of the chemical, plastics and synthetic rubber industries. The variety of products derived from coal is indicated in the diagram on Plate VI.

*Co-operative research on utilisation*

In 1938 the colliery owners of the country joined forces with the combustion appliance manufacturers to form a co-operative research organisation—The British Coal Utilisation Research Association

(B.C.U.R.A.). The initial five years' operations were so convincing to the industrialists concerned that it was decided to put the organisation on a radically different financial footing. To this end the coal-owners decided to institute a voluntary levy of $\frac{1}{10}$th of 1d. per ton of output—realising between £80,000–£100,000 a year—and the other interests, including the coal merchants, also agreed to increase their support. As a result, although the Association is one of the youngest of these organisations, it is now the largest. The case is interesting, as it is at present the only Research Association financed in the main by a voluntary levy on output applicable to a whole industry.

The Association seeks to maintain a balance between fundamental work on the nature of coal and the physico-chemical processes involved, and short-range studies directed to increasing the efficiency of the numerous types of appliance in which coal is used. Its programme covers the whole field of coal utilisation with the exception of coal carbonisation research, which is undertaken by the Fuel Research Board, the Gas Research Board and the British Coke Research Association.

Though sufficient time has not yet elapsed to cite completed and successful items of research there is considerable promise in several of the lines of investigation being followed. An interesting feature of the organisation is the appointment of a Scientific Advisory Panel comprising leading scientific authorities in the fields concerned, who are made fully familiar with the progress of all the work in hand and in prospect. In this way the scientific staff of the Association has the advantage of conferring regularly with leaders in the scientific world.

As soon as possible after the end of hostilities the Association intends to erect new laboratories at Leatherhead on ground contiguous with that to be occupied by several other Research Associations (see Appendix IV).

# CHAPTER 7

# ELECTRICAL INDUSTRY

'Truth is the daughter not of authority but of time.' Bacon's saying is well exemplified by the electrical industry for the audacious quest after truth by scientific leaders in this country and elsewhere has resulted in one of the chief blessings of modern civilisation. Here science has not followed practice, it has led it.

The electrical industry, perhaps more than any other, has been based upon scientific research and invention. It is their continuous application which has achieved the spectacular progress that has been made in the use of electricity. Not only has research been required into the engineering problems involved, but persistent investigation and study of the materials employed have been called for to increase the capabilities and performance of all electrical appliances.

### *Early scientific work*

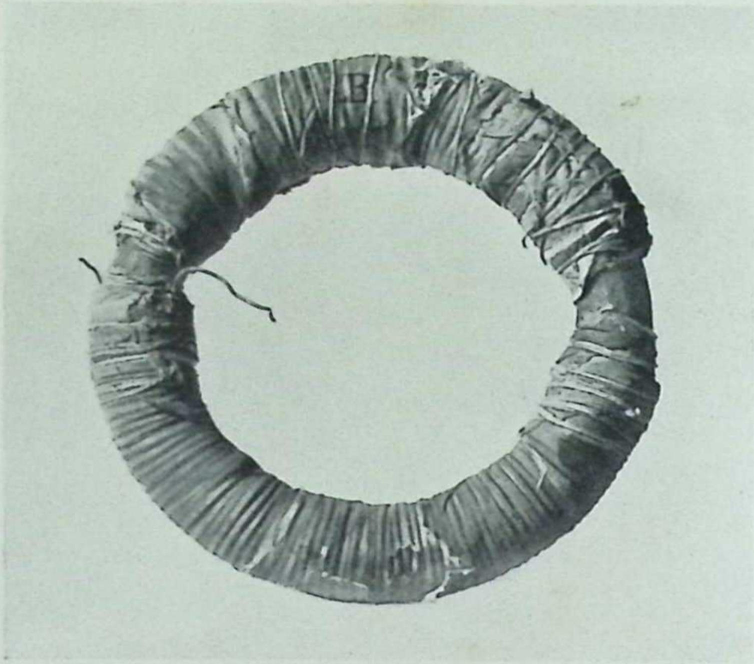
When Michael Faraday discovered electro-magnetic induction in 1831 he laid the foundations of the industry, although some fifty years elapsed before use of his researches on a commercial scale was made. Faraday's discoveries enabled electrical engineering to be soundly based. Thus by the work of Gramme, Wilde, Siemens, Ferranti, Hopkinson, Mordey, Kapp and others, the dynamo, motor and transformer were developed to a high degree of reliability and efficiency. The laws of the magnetic circuit were enumerated by Hopkinson. Due to the invention of high-speed engines and ultimately the steam turbine, generators increased in speed from 500 r.p.m. to 3000 r.p.m. with a reduction in size and corresponding increase in efficiency. It was not, however, until full advantage was taken of Parson's turbine and its development that electrical generation reached real magnitude. That discovery revolutionized central station design and opened up enormous possibilities for electrical generation by large and efficient power units.

To obtain efficiency in generation it was necessary to secure a speed of revolution which no reciprocating engine could produce and the turbine supplied the answer, though high speed reciprocating engines with forced oil lubrication are competitors for certain types of small power plants. The steam turbine is responsible however for about 95 per cent of the electric capacity of the country.

The steam turbine was first used here for the generation of electricity to light the courts of the Jubilee Exhibition at Newcastle-on-Tyne; and in 1892 the first condensing turbine was constructed which halved the



Plate I. Michael Faraday, F.R.S.
Painting by Thos. Phillips, R.A.



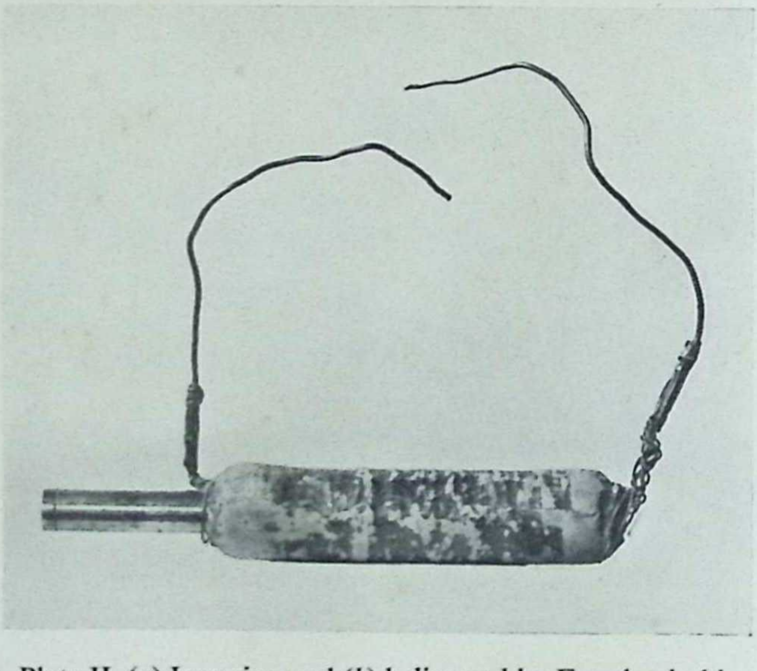


Plate II. (*a*) Iron ring and (*b*) helix used by Faraday in his discovery of electromagnetic induction.

consumption of steam by the earlier types. But between the date of Faraday's discovery and its full scale use by means of the steam turbine and its subsequent improvements, many other notable advances were made. For instance, by 1886 Colonel Crompton had completed a central electric station in Vienna capable of a load-rating of 1000 Kw. and had devised, in collaboration with Professor J. A. (afterwards Sir Ambrose) Fleming, accurate means for electrical measurement. Other outstanding names in the evolution of electrical measurement are Kelvin, Ayrton and Perry (see pp. 160-1).

*Development of power stations*

In this period of advance was Dr. S. Z. de Ferranti, who may be regarded as the originator of early power stations supplying alternating current transmitted at relatively high voltage. While Crompton was a great protagonist of direct current distribution, Ferranti advocated alternating current. He realised the importance of using higher and higher voltages to secure the maximum efficiency of distribution and of generating at places selected so as to secure economy of working. The subsequent establishment of large distribution systems represented later by the Grid was an outcome. In 1890 Ferranti transmitted single phase current at 10,000 v. from his power station at Deptford to London and by 1920 the working voltage of underground cables had been raised to 33,000. During the past twenty years great strides have been made by the application of physics and chemistry to the high voltage electric cable, so that today underground transmission at 132,000 v. is a practical commercial proposition. In all this work the leading cable makers have spent large sums in well laid-out laboratories and much time in solving the various problems involved, thus continuing the pioneer work of a century ago in this country on the use of insulated wires for electric current transmission. About 80 years ago the first submarine telegraphic cables had been the outcome of British enterprise (see p. 206).

During World War II the research resources of the cable industry were taxed to the limit in order to use substitute materials particularly in connexion with cables previously insulated with rubber. Synthetic rubber was introduced to a large extent and plastic materials, particularly polyvinylchloride, were found suitable. Research also enabled greater use of impregnated paper cable for high voltages. Further reference to the use of plastics will be found on p. 129.

*The Grid*

An important step which led to great progress in electrical generation was taken in 1926. In that year the Electricity Supply Act was passed at which time 540 separate power stations were generating electricity at a

wide variety of pressures and frequencies, making interconnexion exceedingly difficult and so encouraging the continuance of a rather parochial system. Under the Act, the number of stations was greatly reduced and by 1935 generation was concentrated in 144 'selected' or 'base load' stations interlinked by a network of mains called the 'Grid' operating at a standard frequency. The electrical output of undertakings in 1925 was 6,665 million units; in 1939 it had risen to 26,409 million units. The initial stages of the Grid were the result of bold trial-installations in the north-eastern district of England during the early years of the century and their success justified the subsequent Act which extended the system over the whole country.

### *Scientific advances since World War I*

It was not until the years of World War I and those immediately following that industrial electrical research reached appreciable proportions in this country, and from that date the institution and development of powerful research departments by the great electrical firms in Great Britain may be traced. The Electrical and Allied Industries Research Association also came into existence at this time.

### *Electric Light*

The development of the electric lamp has probably involved more research on materials and vacuum physics than that of any other mass-produced article. The following table indicates the main stages of development in light efficiencies:

| *Lamp* | *Efficiency in Lumens* per Watt* |
|---|---|
| Carbon Filament | 3·0 |
| Tantalum Filament | 6·0 |
| Straight Tungsten Filament (Vacuum) | 9·0 |
| Coiled Tungsten Filament (Gas-Filled) | 10·0 |
| Coiled Coil Tungsten Filament (Gas-Filled) | 11·5 |
| Neon and Mercury Low Pressure Discharge | 5–15 |
| Mercury High Pressure | 30–70 |
| Sodium Vapour | 30–70 |
| Mercury Low Pressure Fluorescent | 30–70 |

Thus the early carbon filament lamp of Swan and Edison with a light efficiency of 3 or 4 lumens per watt was succeeded by the introduction

* Approximately, a lumen is the amount of light falling on 1 sq. ft., 1 ft. away, from a source of 1 candle power.

of the tungsten lamp and the gas-filled lamp through the work respectively of Coolidge and Langmuir, and by the subsequent improvements described below by British inventors, until a light efficiency of up to 70 lumens per watt has been achieved.

*Discharge lamps*

Discharge lamps operate on an entirely different principle from that of the familiar tungsten filament lamp: the electric current, instead of heating a wire to incandescence, is made to pass through a gas or vapour contained in a sealed vitreous enclosure fitted with two electrodes to convey it to and from the envelope.

Discharge lamps have taken a large number of forms, some of which have now become familiar. Apart from their colour and efficiency, perhaps their next outstanding feature is the enormous range of brilliance obtainable from them. Thus, with certain types of high pressure mercury vapour lamps a brightness equal to or greater than that of the sun have been obtained—that is to say about 300 times the brightness of an ordinary tungsten filament lamp. Such lamps have possibilities for powerful searchlights and other projection purposes. Indeed, there would appear to be no scientific reason why in the course of progress sources giving even higher brilliance of light should not be obtained if desired. Discharge lamps of intermediate brightness—both mercury and sodium vapour types—are extensively employed for street lighting and industrial lighting. Prior to World War II, we had in this country more miles of mercury-lamp lighted roads than all the other countries of the world put together and Britain may fairly claim to have been a pioneer in this important field.

*Fluorescent lamps*

At the other end of the brightness scale, the fluorescent lamp which has about the same efficiency as the high brightness types mentioned above, can be reduced in brightness to about $\frac{1}{600}$th of a tungsten filament lamp. The greatest practical advances in light sources have undoubtedly been made through the application of the phenomenon of fluorescence to discharge lamps. This development depends on the property possessed by certain salts, of emitting visible light when excited by ultra-violet radiation. A low pressure mercury-vapour discharge lamp emits little visible light but generates a large amount of ultra-violet energy, which in a plain discharge tube is absorbed by the glass envelope and is completely wasted. In the most recent types of discharge lamps—the tubular fluorescent lamp—most of this ultra-violet energy is converted into visible light by a thin coating of fluorescent powders on the inside wall of the tubular envelope. The result of this is an increase of more

than 5 times in the light output and, what is scarcely less important, the colour of the light can be closely controlled by using appropriate fluorescent powders or powder mixtures. Thus, what was a defect in discharge lighting—the unusual colour—has been overcome and high efficiency discharge sources, nearly three times more efficient than tungsten lamps and giving colour quality comparable with daylight, are now available.

A word must be said about the fluorescent powders which have made this important lamp possible, for industry in this country has been a major contributor to their development. The powders are for the most part very pure inorganic salts such as magnesium tungstate; and zinc-beryllium to which minute but carefully controlled amounts of certain metallic activators such as manganese are added. To render the materials fluorescent, they are fired at very high temperatures in special furnaces.

*Other advances*

The advances, described above by way of example and in barest outline, by no means embrace all that has been done by firms in the industry. Brief reference must also be made to other important achievements such as the development and production of the coreless induction furnace for the manufacture of special steels and non-ferrous alloys, and the development of high vacuum distillation processes for the separation of vitamin concentrates, and for the production of low vapour-pressure oils suitable for application as working fluids in oil-diffusion pumps to produce high vacuum. The discovery of these oils and their successful application in condensation pumps introduced, as a practical form of engineering construction, the continuously evacuated demountable principle of construction for such apparatus as high power radio transmitting valves, extra high voltage X-ray tubes for deep therapy, special types of cathode ray oscillographs, vacuum furnaces and plant for the production of metallic films by evaporative methods. New types of scientific apparatus have also been made possible, such as the electron microscope (the first one constructed in this country was made in 1935), modern types of which afford enormous magnifications of the order of 10,000. Many new forms of specialised equipment have also been evolved for the furtherance of scientific knowledge, exemplified by the plant used by Cockcroft and Walton in their successful experiments to split the atom. Important contributions to scientific knowledge have, moreover, been made by the study in industrial laboratories of high voltage phenomena and the mechanism of high voltage arc discharges.

Scientific work of a fundamental character has also been extensively carried out by electrical industrial laboratories in allied technical fields.

Two examples are the researches carried out on the order-disorder arrangement in alloys, which have opened up the field of the physics of solids, and the investigation and study, now extending over many years, of the phenomenon of 'creep' in steels under high temperature and high stress conditions. The latter work has led to the development of improved materials of construction for high temperature steam power plant such as boilers, superheaters and turbines, with consequent improvement in operating efficiency and performance, and has played an all important part in maintaining this country in the forefront of progress in the manufacture of such plant. Important contributions have further been made to the art of railway electrification by the development of the 'pumpless rectifier'. Many of the developments have special significance for industries such as radio, which are dealt with elsewhere (p. 209), and references will be found there to such inventions as the Fleming valve in 1904.

The leading firms of the country not only undertake important laboratory investigations but translate into a practical and commercial form the new devices conceived by their scientists—a long and costly operation as a rule. The work of the laboratories is intimately connected with that of development departments and constant interchange of ideas and daily co-operation are essential features. The laboratory is the scientific instrument of the technical departments and both work to a common end.

*Co-operative research*

The industry was one of the first to form a co-operative Research Association. Supported mainly at the outset by the manufacturing firms, it has gradually enlisted the support of the chief supply undertakings of the country from which it now derives about two-thirds of its industrial income. It is one of the three largest Associations in the country. Much of its work has benefited supply undertakings and its well-known research on buried cables is an instance. By that research it was proved that buried cables were capable of sustaining greater loads than had previously been thought feasible. As a result of the research conducted at the National Physical Laboratory over a period of years and costing only £80,000, it has been authoritatively stated that the consequent increase in the value to the owners of the cables then laid in the ground was at least £4,000,000, and that at that date the beneficial effect on the annual outlay on new cables amounted to £250,000 per annum. It is seldom that a cash value can be placed on a research; the benefits are hard to trace and impossible, as a rule, to compute: but in this case the calculation was possible and is spectacular.

The Association has been pursuing over many years notable work on

the fundamental characteristics of arc rupture and the effect of changed rates of rise of recovery voltage, i.e. the rate at which the voltage builds up across a circuit-breaking device when opening a circuit-carrying current; and the effects of pressures due to surges, lightning, etc. One of its outstanding achievements is its work on switchgear, and in this work it has been closely associated with the great firms which specialise in that field. The work on circuit breakers is a fine example of the result of pooling resources by a large group of manufacturers over a period of years and has resulted in contributions of the first importance, not only on the theoretical side but leading to patented inventions now used throughout the industry and paralleling almost every line of development in any part of the world in this important field. Improved arc rupturing devices introduced by the Association made possible a very large increase in rupturing capacity without increase in dimension, and the substantial elimination of risks associated with the use of insulating oil. The Association has established a basis of development for air blast circuit breakers of the highest rupturing capacity.

It is a noteworthy fact that the great firms in the industry, despite their own extensive research laboratories, are strong supporters of the Association and put into 'the common good' more than their monetary contributions, for they render service to the industry as a whole by furnishing, through their representatives on the numerous committees of the Association, a wealth of scientific and industrial experience. Some of the industrial research work is carried out in the laboratories of member firms of the Association. The long range investigations continuously prosecuted by the Association are naturally of great interest to these firms and their implications are readily appreciated by the strong scientific staffs they possess.

In its early years the Association conducted all its work in outside laboratories such as those established by manufacturers, the National Physical Laboratory, and universities, technical colleges and other institutions. Later the Association established special facilities for research not otherwise provided for, and eventually carried out a substantial part of its programme at its own laboratory at Perivale. The industry has outgrown these facilities and much larger premises are to be erected as soon as possible at Leatherhead in close proximity to, and for the mutual advantage of, several other Research Associations which also need increased accommodation to serve more adequately their respective industries (see Appendix IV).

# CHAPTER 8

# FOOD INDUSTRIES

The food industries of the country have been a major concern of the Department of Scientific and Industrial Research and a brief account of the stations devoted to food research will be found on pp. 235-241. The industries dealt with below, several of them in close touch with the Departmental Stations, are all concerned with the question of food production.

## BREWING

### *Nutritional value of beer*

It was not until the middle of the 18th century that tea drinking became general in this country. Previously, beer was the unchallenged national drink of men, women and children at every meal. Its widespread consumption today has a physiological justification. Beer is now known to be a good source of the two vitamins, riboflavin and nicotinic acid, as well as of calcium. The nutritional value of beer confirms the wisdom of the decision to continue brewing during World War II to meet the persistent demand for it from all classes during that period.

### *Size of industry*

In 1870, the number of persons licensed as 'Brewers for Sale' was 28,679. By the beginning of this century, this number had been reduced to 6,290 and of these, 4,759 were brewing less than 1,000 barrels a year. Since then, many absorptions and amalgamations of firms have taken place, the number of individual breweries today, in the United Kingdom and Eire, being less than 500. Very few of them have research laboratories of their own. In addition, however, to their contributions to the research scheme of the Institute of Brewing, a number of firms contribute towards the researches carried on by such institutions as the Rothamstead Experimental Station, the National Institute of Agricultural Botany, the South-Eastern Agricultural College, Wye, and the East Malling Research Station. The Institute itself also makes annual contributions towards the income of these Research Stations.

### *Research agencies*

Research is carried on, directed and controlled by the Institute of Brewing, in the Brewing Schools of the University of Birmingham and

the College of Technology, Manchester, whilst a number of individuals, working either independently or in the laboratories of firms, publish their work as contributions to the Institute's research scheme. The scheme, inaugurated in 1919, is financed by the annual subscriptions, based on output, of 'Corporate Members'. The fund so established, which is under the control of a Research Fund Committee appointed by the Council, is applied and used in promoting and assisting scientific investigation and research for the benefit of the fermentation industries generally. The Research Fund Committee is assisted by advisory sub-committees, appointed for each field of work, the chief of which are: barley, hops and yeast.

*Barley*

The Advisory Sub-Committee on barley began its work in 1922 with a far-reaching enquiry designed to ascertain, *inter alia*, the influence of environmental conditions, i.e., soil, season, and manuring, on the yield and quality of malting barley.

The field experiments were carried out in collaboration with practical barley growers in typical barley districts with a variety of soils and climates, the centres ranging from Southern England to Scotland and from East Anglia to Shropshire and Somerset. Manures were standardised and the seed from one field reserved and threshed for the purpose showed their effect. Valuable data were collected as a result of these trials extending over 10 years, and formed the basis of a voluminous report (*Report on the Ten Years of Experiments under the Institute of Brewing Research Scheme* 1922-31, by Sir E. John Russell, O.B.E., D.Sc., F.R.S.) which was published in 1933.

Before World War II conferences were held annually at Rothamsted between barley growers and malting barley buyers and maltsters. These conferences elicited many points of technical interest and proved of great value. Prior to these gatherings, samples of barley were sent in by farmers from all over the country, with particulars as to variety, soil, preceding crop, manurial treatment and weather conditions from seed-time to harvest. These samples, previously graded by the Valuations Committee of the Institute of Brewing, were exhibited according to the districts of origin and a note on each sample given to the grower concerned. A discussion on the properties needed in good malting barley followed and the principles which guided the Committee in its work of grading the samples were given.

The publication of this report marked the completion of the first phase of the Institute's work on barley and the scientific staff was transferred from Rothamsted to new laboratories in the University of Birmingham, where an experimental brewing plant was installed. A com-

prehensive scheme of research was planned by which, on the transference of the scientific staff, the work at Rothamsted might be extended with a view to tracing the nitrogenous and carbohydrate constituents of barley through the stages of malt, wort and beer.

*Hops*

The work on breeding new varieties of hops was begun at Wye Agricultural College in 1907. The Institute has contributed annually towards the upkeep of the nursery since 1920. The College has thus been enabled to provide for the chemical analysis of hops from the more promising seedlings. Since 1917, valuable assistance has also been given by the East Malling Research Station where a large number of new varieties, raised in the Wye College nursery, have been grown on a commercial scale. These trials have provided information of value to the grower, as well as material for brewing trials. Several of the new varieties have now been sufficiently tested by cultural and brewing trials to enable them to be successfully marketed.

The results of an exhaustive series of experiments carried out at the Institute's experimental oast at Beltring, Kent, have established most of the conditions of drying necessary to secure the best products. Prior to the war these kilns were a centre to which many growers went each year for advice.

The investigations concerned with the preservative properties of hop constituents, carried out in the College of Technology, Manchester, have been brought to a conclusion. The preservative principles have been identified, gravimetric and biological methods have been devised for their evaluation and their fate during the processes of brewing has been determined. A stage has now been reached at which the study of flavour and aroma, apart altogether from questions of preservative value, should yield information which could at once be put to practical application.

The annual visits to hop gardens which, before World War II was a recognised feature of the Institute's work for many years, have afforded opportunities for friendly intercourse between brewers and growers and have done much to enlighten both sides as to their difficulties.

*Yeast*

Work of a fundamental character on yeast is being carried out in the Institute's laboratories and numerous papers have been published.

*Future developments*

Members of the industry have been invited to submit to a Research Panel of the Institute of Brewing suggestions for research or investigation

of general interest. A large number has been submitted covering pure and applied scientific, technological and engineering issues. All the suggestions are being considered by sub-panels, to be arranged by them in order of priority of importance with indications as to which should be dealt with directly by the Institute's staff and which would more appropriately be entrusted to extramural agencies such as an agricultural research station or a university. Estimates both for maintenance and capital costs are to be framed.

In the light of these reports the Research Panel of the Institute proposes to draw up a general scheme for submission to the industry with a view to the necessary funds being raised.

## CONFECTIONERY AND JAM

### *Historical*

The history of the confectionery trade is bound up with that of sugar; before the use of sugar, the only sweetening agency was honey—as Old Testament allusions show.

Sugar from sugar-cane, a plant indigenous from Bengal to Cochin-China, was known in China some 2,000 years before its introduction into Western Europe, although it was known to early Greek physicians. The Arabs cultivated the sugar-cane in North Africa and in the south of Spain in the Middle Ages, and it is still grown near Malaga. The cane was introduced into Madeira in 1420 and into the Canary Islands, Brazil and Hayti in the sixteenth century. In the seventeenth century, it spread to Barbadoes and thence over the West Indian islands. In the Middle Ages, there was some importation of cane sugar into Europe from India and Arabia via Venice for making into marzipan and sweetmeats. The use of sugar in this country is recorded in the accounts of the Chamberlain of Scotland in 1319. By 1598, a German traveller (Hentzer) could refer to 'the great use of sugar' by the English. Nougat was introduced apparently into France from the East about the beginning of the eighteenth century, for it is recorded that to mark the visit of the Dukes of Barry and Bordeaux to the town of Montélimar in 1701, the inhabitants presented them with a 'a quintal of white nougat'.

The use of the cacao bean, from which cocoa and chocolate are made, goes back to 1519 when Cortes found that a cocoa drink was popular at the court of Montezuma. Chocolate as a beverage is recorded as known in Oxford in 1650 and in London chocolate houses existed at the end of the 17th century. Since Samuel Pepys speaks of 'jocolatte' as being very good, presumably it was also known in Cambridge. Chocolate for eating was not made in England until about 1847, when Messrs. Fry & Sons advertised their 'Chocolat Délicieux à Manger'. The firm, founded in

1728, first made chocolate (for the beverage) by means of hand operations; a water engine was subsequently employed, and in 1770 Watt's steam engine. From the date of Watt, mass production ensued; the firm of Terry of York dates from 1767 and was particularly famous for its candied peel and boiled sugar sweets before starting on chocolate manufacture. The firm of Dunhills of Pontefract, the oldest firm making liquorice, was founded in 1760 and Messrs. Cadbury in the 1830's. Messrs. Rowntree had its origin in the small firm of Tuke & Co. in the 1780's, and Messrs. Callard & Bowser of butterscotch fame was founded rather more than 100 years ago.

The leading firms in the industry have extensive laboratories, but these are chiefly devoted to the examination and development of their specialities and to improving existing processes.

### *Jam*

The history of jam making is also linked with that of sugar. In a diary of Henry Machin (1550–1563) 'marmalade' is mentioned. Hakluyt (*Discoveries of the English Nation*, 1598–1600) remarks that the sweets considered necessary for 'banketting on shipboard persons of credite' included marmalade and 'sucket'. Marmalade at that date may well have included a preserve made from fruit other than oranges and 'sucket' was fruit preserved with sugar. Doubtless, jams were made on a small scale in cook-shops; factory production on a large scale does not seem to have been established before the 1880's. In the nineteenth century, jam was a very important commodity in the household budget of poor families, and bread and jam was the chief food of poor children for two meals out of three.

### *Size of the industry*

In 1935, according to the Census of Production, cocoa products amounted to practically 19¾ millions sterling; sugar confectionery, other than chocolate, to practically 35 millions and jam and marmalade to very nearly 7 millions.

### *Co-operative research*

To assist them in the scientific development of the many processes employed, the firms in this section of the food industry (grouped in trade federations known as the Manufacturing Confectioners' Alliance and Food Manufacturers' Federation) formed in 1920 the British Association of Research for the Cocoa, Chocolate, Sugar Confectionery and Jam Trades. Its income in 1923 was £6,830 and had grown to £12,180 by 1943. The organisation is still far from operating on an adequate scale, but despite its meagre resources it has done much for the industry. As

in the case of the Food Manufacturers' Research Association (see p. 56), closer connexions are to be made with the Food Investigation Board. The work of the Board in certain directions can obviously be better pursued in conjunction with the help of manufacturers, and the two Research Associations are favourably placed to secure this co-operation. But both need to be put on a very different financial footing if they are to be of the help they should be.

In its early years the Association's work was mainly devoted to the more obvious and pressing problems and especially to the cause and prevention of defects. Thus 'bloom' on chocolate, mould growth and granulation in jam, bursting of fondant creams, etc., were examined and have been brought under control. The bloom on chocolate, causing a white powdery appearance, due to fat exudation, though entirely harmless, greatly diminished the sale value.

The prolongation of the life of sugar syrups used for crystal coatings to such sweetmeats as peppermints is another example. These syrups can now be boiled up and used again many times without the use of a bleach before becoming too dark. Previously they could only be used three times before undue darkening.

Much long-range research has been done on pectin, the jellying substance of fruits. This has involved a study of its properties and the changes which these undergo in the course of the various stages of jam manufacture. As a result many of the difficulties which existed in the 'setting' of jams have now been overcome.

Sugar, the basic raw material of the industry, has been the subject of much special investigation. This work has shown how the traces of residual substances which are present in even the most highly refined sugars are of importance in the process of confectionery manufacture, and how their effects can be suitably modified to fit in with the requirements of the product. Work has been done on the keeping properties of jam and confectionery. It is now possible to control manufacture so that the goods remain in much better condition prior to sale. This cannot be effected entirely by control of manufacture, however, and the effects of various conditions of storage have therefore been studied. Information has been issued to retailers with recommendations for maintaining their goods in the best possible condition.

Finally, the information which the Association has acquired as the result of research and of its contacts with the food manufacturing industry, has been placed at the disposal of the Ministry of Food during the war. The Ministry has made full use of this offer and a great part of the time of the Association's staff has been so occupied. The Association proposes to build new laboratories at Leatherhead (see Appendix IV).

## FLOUR MILLING

### *Early flour preparation*

Bread is one of the main foods of the human race and the preparation of flour from cereals has been an industry throughout the ages. Wheat is the chief cereal so used. Up to about the middle of the 19th century wheaten flour was produced by stone milling and various improvements were made in the form of mill stones as time went by. But it was with the advent of the roller mill that the industry can be said to have come into the field of the modern engineer; and it was not till the later part of the 19th century that the automatic roller mill was widely adopted.

Wheat is unique among the cereals in containing gluten which owes its existence to the combination of two principal proteins present in the endosperm or floury inside of the wheat berry. Of these proteins one, but not the other, is found in wheat alone among the cereals. To this fact wheat owes its unequalled power of making leavened bread. Wheat is also unique in its milling qualities and for the high yield of flour that can be obtained from it. This is due to the shape of the wheat berry and the properties of its bran coatings; it is also due to the physical properties of the endosperm which is not a mere mass of starch but a structure of starch granules embedded in a network of protein material —the gluten.

### *The roller mill*

The bran is hard and leathery and the purpose of the roller mill is to facilitate its separation from the floury endosperm. The process occurs in two stages. The grain is first passed between grooved rollers running at widely different speeds. Under the cutting and scraping action brought about the berry is opened up and the endosperm in large fragments separated from the bran. The fragments of endosperm are screened out and then passed through relatively smooth rollers running at nearly equal speeds. As a result the endosperm is disintegrated into smaller fragments and the bran flattened so that further sieving enables the endosperm and 'offal' to be separated.

Some idea of the mechanical accuracy of these smooth rollers and of the technical skill required for their construction is furnished by the following facts. The rolls must be true along their whole length, often about 40 inches, and lie truly parallel to each other within a ten-thousandth of an inch. During milling they become warm and a slight expansion occurs which is not uniform at the ends and at the middle of the rolls. One of the pair of rolls is therefore slightly tapered so that when cold a gap of a thousandth of an inch occurs towards the ends of the

rolls when the middle portion is just in contact. Perfect contact is thus obtained throughout the whole length under operating conditions. Not only is this fine mechanism necessary to produce high grade flour but the manipulation of the rolls has to be conducted with skill; the rate of feed and the uniformity of the feeds must be accurately controlled, and the pressure of the rolls adjusted with knowledge and experience.

*Other milling machinery*

There are other sections of milling machinery. The screening and grading of the products from the first set of breaking rollers is controlled by specially designed machinery, the latest form of which, called a plansifter, sorts out the products according to particle size and so classifies the 'break-stocks' as they are termed. All these developments have called for the inventive genius of the engineer and the application of his ideas in machinery of the highest accuracy in construction. These advances, coupled with operative skill in the use of the machines, have placed the uniformity and excellence of British flour ahead of that produced anywhere in the world.

So far reference has been made to milling proper and the share which British engineering skill has had in its development. There is also the earlier process of initial cleaning of the wheat to make it ready for milling. While American technicians have been pioneers in the design of mechanical cleaning equipment, advances made in washing and conditioning wheat have been made in this country and have been adopted on the continent.

*Grain contamination*

Most of the wheat used in normal times in this country is imported from abroad and is, or may be, contaminated in various ways. Seeds of weeds are a source of trouble and weevil infestation is another serious problem. These foreign bodies if allowed to remain have a marked effect on the flour and on the resulting bread.

The infestation of grain and other vegetable products is dealt with more fully elsewhere (p. 240) as part of the work undertaken by Government in the interest of the community. It began between World Wars I and II and was gradually extended as its importance and difficulty were better realised.

The actual removal of the impurities in the form of unsound grain, fine seeds or dust is not difficult. The use of sieves and aspirators achieves that end, but foreign particles of the same size and weight as the wheat kernels present a more difficult problem. An ingenious disc separator and appliances for scraping and polishing the wheat berry

have been devised to get over the trouble; while the washer, primarily a British development, has done much to give a bright clean flour as free as possible from extraneous impurities.

*Conditioning of wheat*

This country having led the world on washing has done so also in the matter of 'conditioning'. It is difficult to over-estimate the advantage the miller of to-day enjoys over his predecessors through modern methods of wheat conditioning, of which the latest is 'hot-conditioning'. Especially is this important in regard to mixed grists. The blending of different wheats is necessary for the production of a flour suitable for the baker; and equally so is their conditioning.

As will have been gathered the operations of the industry depend to a large extent on mechanical perfection of machinery of various types. The efficiency of these machines and also the quality of the flour produced depend, however, on the results of biological research into such problems as conditioning and fermentation, the intimate physical structure of the wheat grain, the distribution of vitamins and minerals in the grain and the chemistry of the wheat proteins. Progress in any one of these fields of research may lead to important practical developments.

*Co-operative research*

In all these directions the British Flour Millers' Research Association has played an active part, e.g. (*a*) Work on the physical properties of dough led to the design of an instrument by which bread quality can be measured. It also enables the miller to mix his wheats in the proportions which will give the best bread. (*b*) A modification in design of plan-sifters has been made, greatly increasing the efficiency of their dressing action. (*c*) It has been shown that flour milling is not a purely mechanical system of disintegration and separation but essentially a manufacturing process during which biochemical changes are produced in the material. Thus it has been demonstrated that a proportion of the individual starch granules undergo a change of structure. The extent of this change has been shown to be of fundamental importance in bread-making and to be susceptible to control during milling. (*d*) The Association has demonstrated that the major part of vitamin $B_1$ in the wheat grain lies in a particular part of the germ called the *scutellum* and that the outer endosperm is particularly rich in iron, nicotinic acid and riboflavin. It is on these facts that the specification of National flour during the war has been based.

On the outbreak of World War II and the control of the flour milling industry by Government, the Research Association's staff and laboratories became the centre of scientific direction of flour production under

Government for the duration of the war, and in 1943 the name of the organisation was changed to the Cereals Research Station, Ministry of Food. Through its agency a specification for National flour was worked out and the Ministry of Food was advised on flour and bread quality generally. By expert analysis the Association kept a record of the quality of the flour and bread milled and baked throughout the country during the war. All this work has been published in the scientific press; moreover, the Association has contributed materially on the nutritional side by improving the methods for estimating vitamin $B_1$, riboflavin, nicotinic acid and the various other factors in flour and bread. No country in Europe during World War II enjoyed better or more nutritious bread than this and the general medical view is that the excellent health of the nation during the war has been due in large measure to the high nutritive quality of the National bread. It was fortunate that a scientific organisation in such direct contact with milling practice was available to serve the national need.

The end result of all the flour millers' work and effort is the baked loaf, and it would seem desirable that the bakers of the country should either join forces on the scientific side with the flour millers, or form a co-operative research organisation of their own which could work in close harmony with the suppliers of their raw material. Consideration is being given to the latter possibility.

## MANUFACTURED MEAT AND FISH FOODS

Closely related to the work of the Food Investigation Board outlined on pages 235-40, is that done by the trade in the preparation of preserved foods. The extent of that trade in 1935 amounted to about 5¾ millions sterling for meat and fish in tins, glass, etc., to nearly 21 millions in bacon, hams and pork, to more than 4¾ millions in sausages and to almost 4 millions in pickles.

### *Historical*

The oldest form of preservation of meat and fish is by drying and possibly smoking. Salting is another ancient practice which was certainly known in Roman times. Home cured bacon was a staple food of the English peasant in the Middle Ages. Piers Plowman's plaint of the lack of it in the off-season, 'I have no salt bacon, ne no cokeney (egg) by Crist!' may be quoted in evidence. In the 14th century, there were two city guilds concerned with fish—the Stock fishmongers dealing with dried fish and the Salt fishmongers who handled salted and pickled fish. They became combined as the Fishmongers Company in 1536. The Salters had a grant of livery in 1394 and is another city guild

showing the early importance of this preservative trade in London. As early as 1382 Yarmouth was a centre of the preserved fish trade.

By the beginning of the 19th century, there were eight methods of preserving food; drying in the sun, using artificial heat, pickling, salting, covering with melted butter, adding sugar, cooling by ice, and the use of charcoal. The last-named process was to remove bad odours, which was deemed equivalent to preservation. During the latter part of this period and the first 30 years of the present century, boric acid or its compounds was used in preserving various foodstuffs, e.g. cream, butter, sausages, and in cooked-meat products sold in open packs. Not all manufacturers used this method of preservation but in the absence of more scientific methods it undoubtedly prevented the wastage of much food. The introduction of the Preservative Regulations in 1925 controlled the use of preservatives and incidentally prohibited the use of boric acid and other potentially dangerous preservatives. At first this action led to serious difficulties in the sale of certain perishable articles such as cream, butter and margarine, but research into other methods of preservation was thereby encouraged, and most of the difficulties have now been overcome.

*Sausages*

The sausage, brought so much to the notice of the British public during World War II and, in its various forms, always a staple item of food in Germany, was well known in Roman times. Sausage making has been a sideline for butchers, and the product being perishable, needs rapid transport for any large scale output. It was not till the 18th century that mass production of various types of sausage was attempted.

*Canning*

Canning dates from the end of the 18th century when a Frenchman (Nicholas Appert) won the prize of 12,000 francs offered by the French Government in 1795 for an invention for preserving foods—an instance of Napoleonic foresight. Appert's process was based on the then current theory that contact with air is the chief cause of putrefaction. Fortunately his method entailed heating to a sufficient degree to destroy micro-organisms. Stoppered jars full of food were heated in boiling water and on this principle Appert processed meats, vegetables, fruits, and milk. The French Navy tried out the products about 1806, and three years later the prize was awarded. In 1811 the process was developed in this country and Napoleon enjoyed the results at St. Helena.

As proof of the effectiveness of these early canning processes, it is interesting to note that in 1938 a 4 lb. can of roast veal prepared in

1824 for Capt. W. E. Parry's third voyage for the discovery of the North West Passage was examined. This can was removed from the *Hecla* after the third voyage and taken out to the Arctic on the fourth voyage in 1826. The meat was in good condition and vitamin D had survived; there was a high proportion of tin in solution, not unnatural after 114 years.

Improvements in the cans used were made in 1833 by the lid being flanged and soldered on. A small vent hole was provided to allow the escape of air during heating and the hole was soldered immediately afterwards. By 1885, cans were being made entirely by machinery. Considerable extensions of the canning industry especially for fruits and vegetables have been made in recent years and the Research Station at Chipping Campden has given much assistance to growers.

*Co-operative research*

In 1925 the British Food Manufacturers' Research Association was formed and was supported until recently only by the processed meat and fish section of the trade. A section for pickles and sauces was formed early in 1944. The income of the Association has been small. In 1927 it was only about £2,500 and in 1944 £8,554, but the organisation has been conducted in close conjunction with, and in the premises of, the Confectionery Research Association referred to earlier, so that some saving in overheads has been secured. Even so, the financial resources of the organisation are quite inadequate to serve the industry properly. Close co-operation with the Food Investigation Board has been maintained, and the connexion is likely to be closer still in the future.

The work of the Research Association falls into several categories and covers a fairly wide range of subjects, e.g., bacon curing, meat and fish canning, cooked meats, sausages and, more recently, problems connected with pickle and sauce manufacture. A large part of the work is of a fundamental nature dealing with the bacteriology of meat and bacon curing, the sterilization of canned products and the preservation of cooked meats. The curing of vegetables for use in pickles and sauces, and their preservation, have hitherto been carried on by rule-of-thumb methods. Much fundamental work is required to put the industry on a proper scientific basis. Another part of the work deals with defects occurring in finished products, e.g., corrosion of cans and metal lids, and defects due to faulty processing. Bacteriological hygiene in factories, and the processes used in handling meat and fish products, generally call for short-term investigations. Special problems arising in particular factories are also dealt with.

The Association has developed two special instruments which have proved of considerable value. One of them is for the purpose of measur-

ing the salt in pickled and cured meats. The rate at which the salt penetrates can be measured and thus the length of time required for curing determined. The instrument has also been found of service in the selection of cured gammons used for canning. The other instrument is a specially accurate vacuum gauge for determining the true vacuum in cans.

The Association proposes to build new laboratories at Leatherhead (see Appendix IV).

## SUGAR

Sugar is one of the most important energy producing foods available to man. The ease with which it is absorbed makes it particularly vital to those whose metabolism has sudden or sustained demands made upon it—the growing child, the athlete, the manual worker and the sailor, soldier and airman. No nation can afford to neglect its source of sugar supply either in peace or war.

### *Sources and size of sugar industry*

Until the end of the 18th century the world's sugar needs were supplied from the sugar cane grown in the tropics, but about 1800, as the result of successful experiments by a German chemist, a factory was built in Silesia for the manufacture of sugar from beet. Napoleon gave a great impetus to the industry in France at the beginning of the 19th century when the British navy blockaded his ports. He enforced the growing of beet for sugar and within fifteen years more than 200 small factories producing 40,000 tons per annum were established. Nor was this all; it was found that in those districts supplying the beet factories with their raw material the production of corn and livestock increased owing to the beneficial effects of the beet crops on the soil. Students of economics and of agriculture were not slow to realise the many advantages to continental countries of growing sugar-beet. The beet sugar industry continued to make rapid progress and in 1884 nearly 2½ million tons of sugar were produced. Reference to the sources of cane sugar will be found on page 50.

The demand for sugar, both cane and beet, and foods containing it, steadily rose in all countries where the standard of living was highest, notably the U.S.A. and Great Britain, and under this stimulus the production of sugar rose accordingly. Between 1863 and 1903 the world production increased from 3 million to 12½ million tons and at the outbreak of World War I the production increased to nearly 20 million tons, of which cane and beet produced roughly equal proportions.

World War I severely reduced the supply of continental beet sugar.

This fact, together with the rise in world prices, gave an opportunity to cane-sugar countries to increase their output to nearly 80 per cent of the world production. It was not until 1927 that the beet-sugar industry regained its pre-war output. In the meantime the cane-sugar countries further increased their production to meet the growing demand for sugar. At the outbreak of World War II the world production of sugar reached 29 million tons of which the beet-sugar industry contributed 36 per cent.

The accompanying graphs show (*a*) the world production of cane and beet-sugar and (*b*) the imports of raw and refined sugar from British and foreign sources, together with home production.

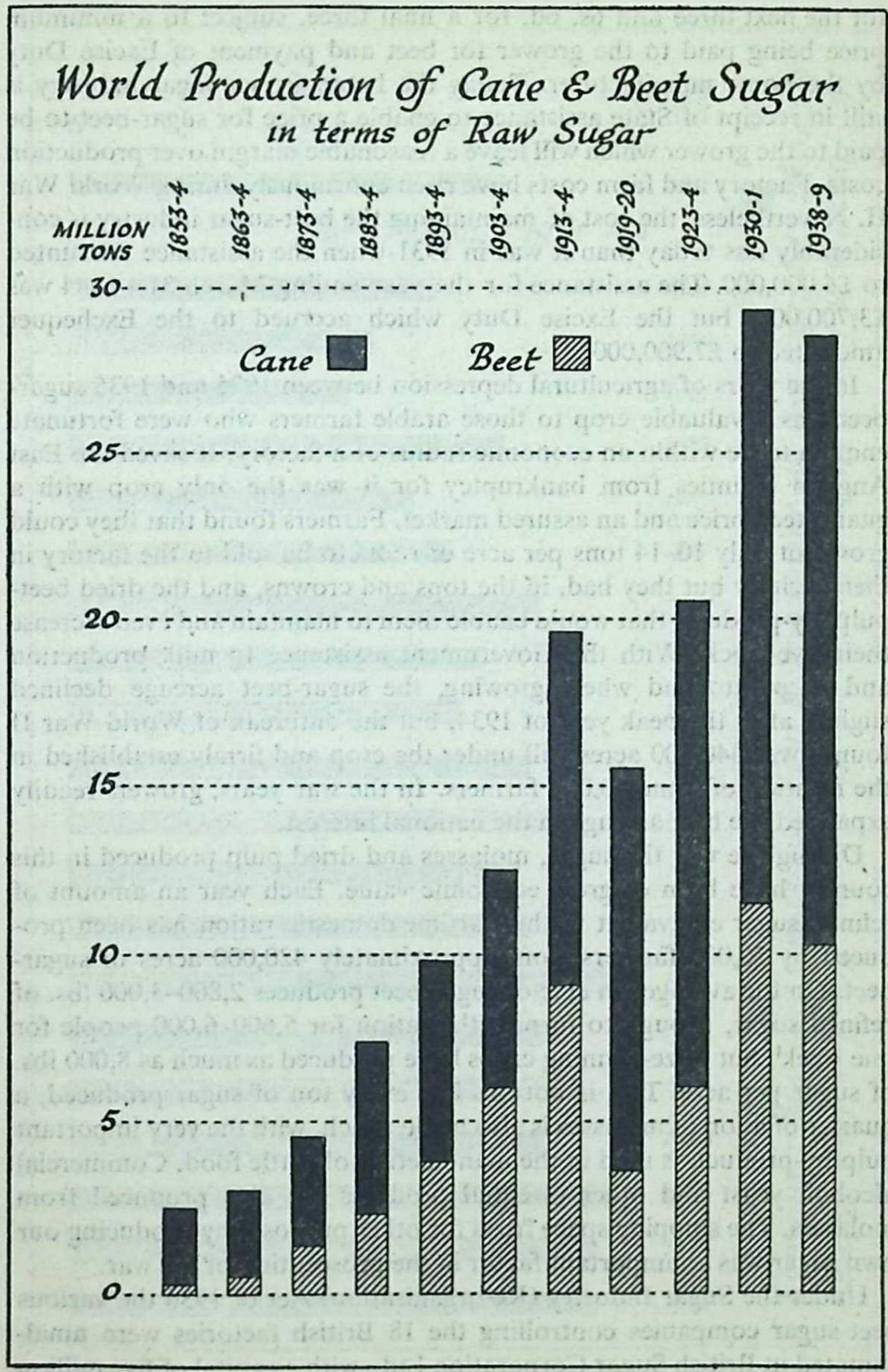
*Beet-sugar in Great Britain*

Prior to World War I the sugar requirements of this country had to be met by importation; about 80 per cent came from the sugar-beet fields of the continent and the remaining 20 per cent from cane-sugar producing countries. Continental countries relied almost entirely on their home-grown beet sugar, and suffered less than Great Britain from sugar shortage during 1914–18.

Sporadic efforts were made during the latter part of the 19th century and the beginning of the 20th to establish this agricultural and manufacturing industry in the United Kingdom, but with small success. Failure was due more to lack of political support than anything else. It was found that the English climate was particularly suitable to sugar-beet and that in East Anglia especially, the farmers would welcome the establishment of an industry which would give them not only an assured market and valuable agricultural by-products, but also improve the soil for their crop rotation.

The Earl of Denbigh was the first to carry out experiments with sugar-beet in England. On his estate in Warwickshire he sowed a few acres and proved that it could be grown profitably. Eventually the National Sugar Beet Association was formed in 1910 and experimental crops were organised over a wide area. But it was left to a Dutch firm to erect the first English factory at Cantley in Norfolk in 1912. The lessons of World War I, however, changed the entire outlook. An important group in Parliament became interested, with the result that the Sugar Beet Society was formed to provide expert advice to the would-be beet grower and to continue the propaganda already begun for the establishment of this new industry.

In 1925 the Sugar (Subsidy) Act was passed. Under its provisions Government assistance was given in the form of grants on sugar and molasses made from home-grown beet. The subsidy on sugar was on a declining scale at the rate of 19s. 6d. per cwt. for the first four years, 13s.

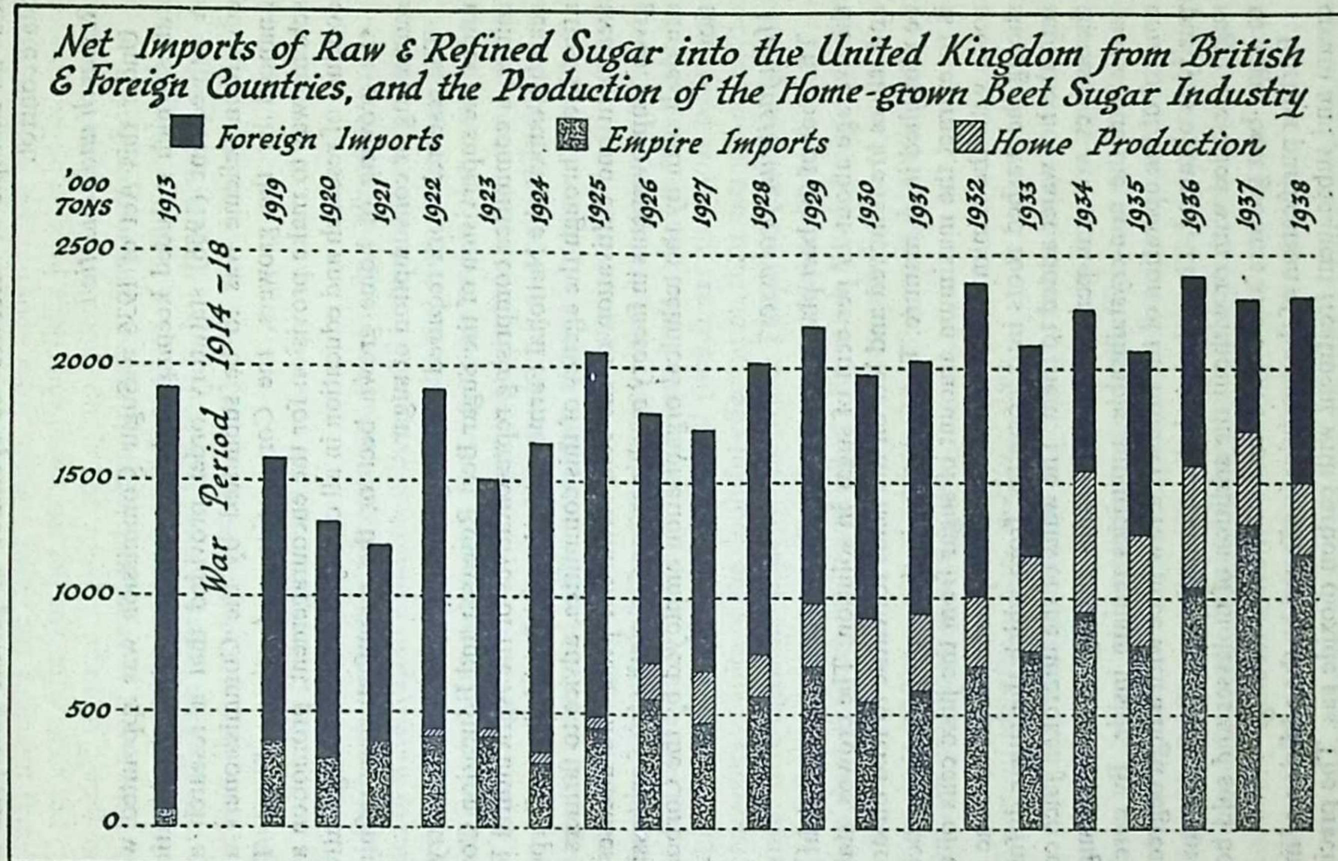

World Production of Cane & Beet Sugar
in terms of Raw Sugar
MILLION TONS
1853-4
1863-4
1873-4
1883-4
1893-4
1903-4
1913-4
1919-20
1923-4
1930-1
1938-9
30
25
20
15
10
5
0
Cane
Beet

for the next three and 6s. 6d. for a final three, subject to a minimum price being paid to the grower for beet and payment of Excise Duty by the home manufacturer. Today the home-grown sugar industry is still in receipt of State assistance to enable a price for sugar-beet to be paid to the grower which will leave a reasonable margin over production costs. Factory and farm costs have risen enormously during World War II. Nevertheless, the cost of maintaining the beet-sugar industry is considerably less today than it was in 1931 when the assistance amounted to £6,000,000. The assistance for the year ending March 31st 1944 was £3,700,000, but the Excise Duty which accrued to the Exchequer amounted to £7,900,000.

In the years of agricultural depression between 1925 and 1935 sugar-beet was a valuable crop to those arable farmers who were fortunate enough to be within an economic radius of a factory. It saved the East Anglian counties from bankruptcy for it was the only crop with a guaranteed price and an assured market. Farmers found that they could grow not only 10–14 tons per acre of roots to be sold to the factory in their vicinity but they had, in the tops and crowns, and the dried beet-pulp, by-products that would enable them to maintain and even increase their live-stock. With the Government assistance to milk production and to potato and wheat growing, the sugar-beet acreage declined slightly after the peak year of 1934, but the outbreak of World War II found over 340,000 acres still under the crop and firmly established in the rotation of some 40,000 farmers. In the war years, growers readily expanded the beet acreage in the national interest.

During the war the sugar, molasses and dried pulp produced in this country have been of great economic value. Each year an amount of refined sugar equivalent to the wartime domestic ration has been produced by 50,000 farmers from approximately 420,000 acres of sugar-beet. On the average, an acre of sugar-beet produces 2,800–3,000 lbs. of refined sugar, enough to furnish the ration for 5,600–6,000 people for one week; but prize-winning crops have produced as much as 8,000 lbs. of sugar per acre. This is not all. For every ton of sugar produced, a quarter of a ton of molasses is also made which, with the very important pulp by-product, is used in the manufacture of cattle food. Commercial alcohol, yeast and other essential products are also produced from molasses. The shipping space freed for other purposes by producing our own sugar was an important factor in the prosecution of the war.

Under the Sugar Industry (Re-organisation) Act of 1936 the various beet-sugar companies controlling the 18 British factories were amalgamated in British Sugar Corporation Ltd., with a capital of five million sterling. The chairman of the Corporation and certain members of the directorate are nominated by the Government. The sugar industry is


Net Imports of Raw & Refined Sugar into the United Kingdom from British & Foreign Countries, and the Production of the Home-grown Beet Sugar Industry
Foreign Imports
Empire Imports
Home Production
'000 TONS
1913
1919
1920
1921
1922
1923
1924
1925
1926
1927
1928
1929
1930
1931
1932
1933
1934
1935
1936
1937
1938
2500
2000
1500
1000
500
0
War Period 1914–18

thus an example of successful co-operation of private enterprise and State control.

*Research and education*

Under this Act of 1936 a Sugar Commission was appointed with duties which included keeping under review research and education. A subsequent (1938) statutory order provided that a research and education scheme was to be submitted by the Commissioners and financed by the growers, the Corporation and other refiners. The scheme was to make provision for the encouragement, promotion and conduct of research and education in all or any of the following matters —the growing of home grown beet or the manufacturing, refining, marketing or consumption of sugar.

The research work required on the agricultural side of the industry is under the supervision of the Sugar Beet Research and Education Committee, a committee comprising representatives of the Agricultural Research Council, the National Farmers' Union and British Sugar Corporation Ltd. Through the agency of this committee, advice to farmers on treatment and cultivation of the soil, fertilisers, pests and diseases is given. Improvements in factory machinery and in methods of processing are dealt with by the technical organisation employed by the Corporation.

*Manufacturing processes*

The root of the beet plant as sent to the factory contains by weight on the average about 17 per cent of sugar in solution. The crowns, stalks and leaves are removed and left on the fields for cattle to feed on or to be ploughed in as manure. The first stage in the manufacturing process is to extract the maximum amount of sugar from the juice cells of the roots with the minimum of other impurities present. This is done by slicing the washed roots into 'cossettes' from which the sugar diffuses into the hot water added to them. The walls of the unbroken juice cells themselves are semi-permeable membranes through which the sugar passes but the non-crystallisable impurities remain inside. By careful control of the operation of the diffusers a raw juice with a high degree of purity is obtained. The exhausted slices, containing a small amount of sugar are dried with or without the addition of molasses and sold both to sugar-beet growers and other farmers for cattle feeding.

Further purification of the raw juice is effected by the addition of lime cream and subsequent treatment with carbon dioxide gas. The precipitated impurities are removed by filtration after each of the various stages. Final treatment with sulphur dioxide gas, and sometimes with decolourising carbon, removes a good deal of the colour. Concentration

in large evaporators of this purified 'thin juice' (now almost water-white) increases the sugar content from about 12 per cent to at least 65 per cent. After further treatment this 'thick juice' is boiled up into a 'magma'* of sugar crystals and syrup called a 'massecuite', and from this the sugar is separated by centrifuging. The mother-liquor is collected and reboiled to produce further crops of sugar crystals. When the purity of these 'green syrups' falls so low that they refuse to crystallise further, they are discarded as a very dark and viscous fluid called 'molasses'.

*Beet effluent*

During the manufacturing process, thus briefly outlined, large quantities of water (up to 4 million gallons per 24 hours) are used, mainly for washing and 'fluming', i.e., conveying the beet from the storage 'silos' to the factory. This water rises in temperature and is also contaminated with soil, sugar and various impurities from the process. It is thus liable to cause pollution in the rivers from which it was originally drawn, even after the suspended solids have been removed by sedimentation in the factory settling-ponds. The factories have endeavoured to eliminate this trouble and considerable improvements have been made in the quality of the effluents since the factories were built. Most factories are now able to re-use their 'process-waters' (which are the most polluting in character) in spite of the doubtful effect upon their extraction performance. Investigations made by the Water Pollution Research Board of D.S.I.R. have shown that these process-waters can be purified by passing them through biological filters. Research is still being carried on with the help of the Water Pollution Research Board at some of the factories with the object of finding the best practical solution to a very difficult problem (see also p. 287).

*Essential identity of cane and beet sugar*

A popular misapprehension attributes to cane-sugar qualities superior to those possessed by sugar made from beet: in fact, the sugar derived from both sources is essentially the same. There is no technical disadvantage in the use of home-grown sugar for the canning and preserving of fruit. Experiments conducted under the auspices of the Ministry of Agriculture at Chipping Campden have demonstrated the complete suitability of beet-sugar for the making of jams, jellies and other preserves and for the preparation of syrup for fruit-canning.

* A 'magma' is the residue that remains from a semi-liquid substance after the liquid part has been removed by pressure or evaporation.

# CHAPTER 9
# GAS

## *Early years*

Coal gas illumination in place of oil lamps dates from the beginning of the 19th century and the first gas undertaking in the country, the Gas Light & Coke Company, received a charter in 1812. As its title implies, its dual object was to supply light from gas and to make coke as a residual product. By the middle of the century, most large towns had some form of gas supply and it was not until the 1880's that electricity began to compete with it. Many readers will recall the days when the fish-tail burner served to light their houses and the lamp-lighter went his street rounds at dusk.

Probably the greatest event for the gas industry was the discovery, in 1855, by the German chemist Bunsen, that by mixing air and coal gas, a flame with an intense heat could be produced. Gas then became increasingly important as a heating medium in addition to its use for illumination. As an illuminant it was given a new lease of life in 1885 by the invention by an Austrian, Welsbach, of the incandescent gas mantle which, coated with oxides of certain metals, was heated by a Bunsen flame to give a light source eight times brighter than that of a gas flame. Some years later an alternative process to carbonisation was introduced by the manufacture of carburetted water-gas. The poor quality gas produced by the action of steam on hot coke was enriched by hydrocarbons of high calorific value produced by the 'cracking' of oil. Whilst the use of gas as an indoor illuminant has gradually declined, large quantities are still being used for street lighting; not less than 56 per cent of all public street lamps in this country in 1937 being lit by gas.

## *Gas for heat*

The application of gas for heating grew rapidly. In 1882 there were 400 companies and undertakings making 66½ million cubic feet, and by 1912 the number had more than doubled and the output trebled. In 1938 the output had risen to 340 million cubic feet for which about 18½ million tons of coal were used. Further, some coke-oven plants produce more coal gas than they need for their own works and the surplus gas is piped to adjacent gas undertakings where it is purified to make it suitable for admixture with town gas. In 1937, coke-ovens supplied gas to some 45 gas undertakings, the quantity amounting to

nearly 7 per cent of the total gas supplied to consumers. By the close of the 19th century, gas cookers and gas fires were coming into general use: gas water-heaters for baths and washing-up etc. were introduced, and the use of gas was steadily extending in various branches of industry for heating purposes or for driving engines where steam power was inconvenient. About 70 per cent of the cooking load of the country is borne by gas; the rest by coal and electricity the latter about 4 per cent. By the Gas Regulation Act, 1920, the heating or calorific value of gas replaced cubic feet as the standard upon which gas charges are based.

*Gas production and by-products*

The processes for the carbonisation of coal have steadily improved through the years, in methods of charging, in the design of retorts, in thermal efficiency and in methods for the purification of gas and the recovery of by-products. Horizontal retorts are still used but approximately half the gas-making load is now borne by continuous vertical retorts. In both cases the severe thermal conditions are met by the use of high quality refractory materials in the construction of the retorts. Mechanical stokers have replaced shovelling of fuel for the firing of the retorts. The conversion of coal into gas, coke and by-products is a process of high thermal efficiency, 75–80 per cent efficiency being maintained in good operations. The purification of the gas has received even more attention. In the early days the ammoniacal liquor that was produced was discreetly disposed of, but soon use was made of it and for a considerable time the waste liquor provided the main source for the manufacture of ammonium sulphate. More recently the production of synthetic ammonia and its salts has competed with the gas product. In 1921, 116,000 tons of ammonium sulphate were produced by gas undertakings; in 1930 125,000 tons, but in 1935 only 77,000 tons. Much of the ammonia produced at gas works is now being converted into concentrated ammonia liquor which is used by the chemical industry for a variety of purposes.

The purification of coal gas from hydrogen sulphide was, at first, a difficult problem but the use of iron oxide to absorb hydrogen sulphide (introduced in 1850) has resulted in modern methods of high efficiency. The spent oxide containing about 50 per cent of sulphur is used for the manufacture of sulphuric acid and provides 27 per cent of the total production of this acid or 220,000 tons a year. An important by-product of the industry is tar, used not only in a crude form, but as the source, on distillation, of a large number of highly important hydrocarbons used for dyes, drugs and scents as well as for synthetic resins and plastics. Benzole is also recovered from coal gas (up to 4 gallons per ton of coal) and is of great importance as a high-grade motor fuel and

for conversion into a variety of chemical products. These various by-products have become highly important sections of the industry which link it with many others dependent on gas by-products for a large portion of their raw material. The production of tar increased from 160 million gallons in 1921 to 220 million gallons in 1935.

*Coke*

The gas industry uses annually in carbonisation, from 18–20 million tons of coal from which about 11–12 million tons of coke and breeze are produced. The bulk of the coke is used as a smokeless fuel in hot water boilers and domestic grates and for commercial and industrial heating purposes. Gas works coke is lighter and more combustible than that from coke-ovens. The latter is hard and dense and used primarily for metallurgical processes (blast furnaces, foundries). The demand for metallurgical coke in times of industrial prosperity is great and both sources of coke supply are fully absorbed, but in times of industrial depression there is an increased tendency for coke-oven coke to compete in the domestic market. There is, however, a considerable degree of co-ordination between the gas and coke-oven industries in supplying the large and various demands for coke.

*Distribution*

A major item of expenditure by gas undertakings is incurred on distribution, for mains have to be laid and kept in repair. In certain areas, gas-grids for the distribution of gas in bulk over considerable distances have been developed, notably in parts of Yorkshire and in N.E. England. This is a field of investigation to which the industry is likely to devote attention, in order to effect smaller capital outlay. In any such endeavours, scientific examination of the type of pipe best suited to withstand corrosion and up-to-date methods of pipe construction and laying may lead to further advances, as for instance distribution of gas under considerable pressure (200 lbs per sq. in. or more), a method by which Hanover was supplied before World War II from the Ruhr.

*Research*

The gas undertakings and the plant and appliance manufacturers in the industry were spending, before the war, about £400,000 a year on research and development. In addition, in 1939 the Gas Research Board was formed to carry out new work on the processing of coal and the utilisation of its products. This work is complementary to the research and development work done in industrial laboratories. One of the major difficulties in the industry at present is the interdependence of coke and gas. Processes under investigation by the Gas Research

Board have as their objective the complete gasification of coal, so that the amounts of coke and gas may be adjusted to the demands for each at a particular gasworks. Besides studying the processing of coal, the Board is pursuing work on the utilisation of the products formed. In this connexion it is interesting to note that a ten per cent saving in the efficiency in utilising gas would reduce the cost to the consumer by about three times as much as a ten per cent gain in efficiency of manufacture, because of the distribution and maintenance costs involved.

The work of the Gas Research Board may well lead to increased flexibility in gas manufacture, to distribution of a gas which will not produce appreciable quantities of corrosive products, to improved methods of burning gas and of extracting the heat from the products of combustion, and finally to the production of materials of value to the chemical industry in Great Britain.

# CHAPTER 10
# GLASS

### *Historical*

Although there may have been earlier attempts in Great Britain over several centuries to practise the craft of glass making, little of a definite character is known until the beginning of the 12th century when glass makers from Normandy settled in the woods of Surrey and Sussex and, gradually extending their operations, carried on their craft for the next three or four centuries. The sites of many of these old factories have been excavated. New impetus was given to glass making in this country, first by the temporary settlement for a few years in London in the middle of the 16th century of a band of glass workers from Murano and of subsequent groups who were from time to time induced to come. Immigrant glass makers from Lorraine, in the second half of the same century, found their way gradually across the south of England and eventually settled, some temporarily at Eccleshall in Staffordshire; others permanently in South Staffordshire near Stourbridge and at Newcastle-on-Tyne. Backed by Royal or Government assistance and by the hard work of several outstanding Englishmen, this country slowly acquired during the 17th century a definite position amongst glass-making countries. During the 17th and 18th centuries, England made several noteworthy contributions to the art and craft. It was the first country to introduce coal as the fuel for furnaces; it introduced covered fireclay pots; it made an outstanding contribution by introducing an alkali-lead oxide-silica glass for extensive use for drinking and similar domestic vessels, whereas throughout all the preceding centuries there had been but one kind of glass, that composed of alkali-lime-silica. This lead glass was suitable for cutting and engraving, processes which were adopted early in the 18th century, and English cut-glass began to achieve a reputation which led to it becoming a formidable rival throughout Europe of Venetian glass. The English glass furnaces of the 17th century were also notably in advance of other types in Europe. From the middle of the 18th to the middle of the 19th centuries, this country was a large exporter of glass. From 1850, and particularly from 1870 onwards, the industry in other countries, particularly Germany and Austria as well as America, began to expand, largely assisted by subsidies and sheltered by protective tariffs; and the British glass industry slowly began to decline. In 1938, the world order of glass-production was the United States of America, Russia, Germany, Great

Britain. At the present time, the most important glass-making areas in this country in order of weight of production are Lancashire (mainly St. Helens), the West Riding of Yorkshire, the London area, Birmingham and South Staffordshire (Stourbridge area), the north-east coast and Scotland.

## *Glass bottles and jars*

Great Britain for two-and-a-half centuries has been a substantial producer of glass bottles and jars. This section produces not only by far the largest quantity of glass by weight, but also the largest in value. The first patents in any country for making bottles by machinery were taken out in this country more than 80 years ago and the first practical bottle-blowing machine was that of H. M. Ashley of Ferrybridge, used commercially in 1887. At the close of the 19th and the beginning of the 20th century, British semi-automatic machines for bottle making were coming into extensive use, in advance of any other European country. Nevertheless, early in the 20th century, continental bottle makers were making serious inroads into our export trade. In America, considerable development in bottle making took place in the closing years of the 19th century and one of their machines, the invention of M. J. Owens—developed 1898–1904—was fully automatic with six arms, each constituting a bottle-producing unit and having a productive capacity far in advance of any other machine. It was set up in England in 1907 and led to a great change in the distribution of production in Europe and in the allocation of markets, because the European bottle makers found it necessary to unite to purchase the European patent rights of the Owens machine. During the years immediately preceding World War I the bottle-making industry in England was again making progress and undergoing considerable mechanisation mainly with semi-automatic machines. At the close of that war, other types of American automatic glass bottle-making machines were introduced. These newer types were charged automatically with glass by so-called 'gravity feeders' as opposed to the principle employed by Owens of sucking up into the mould the molten glass required to form the bottle. By 1925 this country was already equipped with automatic bottle-making plant much in advance of any other European country. Generally speaking, it has continued to hold the lead.

## *Flat glass and constructional glass*

The flat and constructional glass section of the industry includes sheet glass, drawn or blown; rolled glass in its various forms of polished plate, figured rolled glass, wired glass, coloured and opal glasses, including

Vitrolite, hollow glass building blocks, toughened lenses to be set in concrete as roof lights, pavement lenses and sundry other forms of glass, including the new cellular or foam glass.

The manufacture of sheet glass has been carried on for many centuries in this country. During the last half of the 19th century and until the close of World War I the chief method of producing sheet glass as distinct from plate was by blowing a large cylinder, splitting it lengthways and flattening the segments in a flattening furnace by means of a damp, charred block of wood. Cylinders were made by hand up to a maximum length of about 6 feet with a diameter of 12 inches. Lubbers, between 1898 and 1904, developed in America a mechanical method whereby much larger cylinders could be drawn. Before this process in turn was displaced, cylinders up to 40 feet long and 40 inches in diameter were made and, even though each long cylinder had to be split into several sections for ease of manipulation, sheets of much larger area were obtainable than from the hand-made cylinders. The production per unit of labour was also far higher. Lubbers' process was acquired by the American Window Glass Co., whilst in this country Messrs. Pilkington Brothers installed it in 1909, being the first firm in Europe to adopt this large scale method.

Within a few years of the close of World War I, the cylinder process, save for coloured sheet manufactured by the hand-cylinder process, was displaced by a method in which the sheet was drawn direct from the furnace. Two inventors at the beginning of the century independently devised processes for drawing sheet glass, namely, Fourcault in Belgium in 1903 and Colburn in America in the same year. Both processes needed the expenditure of a great deal of capital and of development work to bring them to a commercial stage. The Fourcault process, although working on a limited scale in 1912, came into commercial production in Belgium and in Czechoslovakia in 1919. The Colburn process, which was taken up by the Libbey-Owens Co., in 1912, began successful commercial production in 1918.

The rights for the Fourcault process for most of the countries of the world, except Belgium, Czechoslovakia and France, were acquired by a British group which began to operate it in 1924. A modification of the Fourcault process, known as the Pittsburgh process, has also been adopted in this country, but not the Libbey-Owens (or Colburn). The Fourcault, the Libbey-Owens and, in a few instances, the Pittsburgh process, have however been adopted in many countries throughout the world. By all these methods, sheet glass ranging from very thin up to ¼ in. thickness (or even more) can be drawn. Each process is fully automatic and continuous (24 hours a day) and the productivity is very great. The adoption of these processes has led to the concentration of

production in a small number of works and the closing down of a large number of those which employed the cylinder process.

A contribution to sheet glass of high quality was made by Messrs. Chance Brothers in the second half of the 19th century, when they selected suitable sheet glass and subjected it to a polishing process, the product being known commercially as 'patent plate'.

Plate glass is obtained by rolling molten glass either on a long fixed table by a single roller or between a pair of rollers. The plate so rolled then needs to have each face ground flat by sand (or other abrasive) and water by means of a disc shod with cast iron grinding pads or 'nogs'. The plate is subsequently polished with rouge and water, by rotating felt-covered polishers. Revolutionary developments have taken place in the manufacture of polished plate and Great Britain has taken a leading part in them. Thus, the principle of rolling with double-rollers was due to Mason and Conqueror and to Chance Brothers, Ltd., who bought their patent and developed this invention as far back as 1884–1890. This double-roller principle was adopted in the new Bicheroux plate glass process some 20 years ago. It was also used by Henry Ford in America and by Pilkington Brothers in England in 1924 in their still more revolutionary method of obtaining glass by melting it in a large tank furnace and allowing it to flow out continuously in controlled amount between the rollers. In the earlier processes, the glass had been melted in large fireclay pots holding between 1 and 2 tons, the contents of which were poured in front of the single roller or between double rollers. Pilkington Brothers also developed a process for the continuous grinding and polishing of plate glass. In the latest process, also due to the same firm, both sides of the plate of glass, about 100 inches wide, are simultaneously ground and at a later stage simultaneously polished. The whole course of manufacture is a continuous one from the delivery of the raw materials into the melting furnace, until the band of plate glass has passed from the long annealing furnace into and through the grinding and polishing chambers. This latest process also yields polished plate of a higher level of quality as regards parallelism than previous methods. Figured glass (developed by the Glasgow Plate Glass Co.) was produced by the table method about 1890 in which the table carried the pattern to be imprinted on the glass and this method was later improved by double rolling, as described above, but using two pairs of rolls, one of the second pair carrying the imprinted pattern.

Wired glass has also been greatly improved by British endeavour. Instead of laying the wire on a freshly rolled sheet of hot glass and allowing it to sink and be submerged, the method now employed is to sandwich the wire between two thinner sheets of hot glass which fuse together

and imprison the wire while leaving both external glass surfaces smooth and unbroken.

Opal plate, including Vitrolite and varieties of coloured polished plate, is melted in pots, rolled on a table by a single roller and subsequently ground and polished. Glass building blocks have been quite extensively used in America and to a small extent in this country, in Europe and in Australia. The types made in this country are similar to the American. They are produced from two sections each pressed into the form of a shallow rectangular dish, on the inner large surface of which a ribbed or prismatic pattern is impressed. The edges of the two sections are then put together and sealed.

### *Safety glasses*

Laminated glass and heat-treated glass are modern developments arising from the search to enhance the strength of glass used in transport vehicles and to render as harmless as possible any pieces of fractured glass. The possibilities of laminated glass were thought of by C. J. Wood in this country, but patents covering the idea were first taken out by a Frenchman from whom the Triplex Safety Glass Co. acquired them and began to manufacture Triplex glass in 1912. The manufacture of laminated glass, consisting of two pieces (thin plate or thin sheet) with a very thin interlayer or sandwich of a plastic material like cellulose nitrate (displaced later by cellulose acetate and still later by newer plastics of the vinyl type), was developed extensively in this country many years before it was undertaken on the continent or in America.

Bullet-resisting glass for bombers and tank windows is a special development in which this country has taken a prominent part. The heat-treated type is prepared from plate glass and, in this country, is called 'toughened' or 'Armour plate' glass. The average tensile strength of glass is about 2 tons per sq. in., but a tensile strength of 10–12 tons per sq. in. can be attained by toughening. This is done by heating the glass until it is just beginning to soften and then chilling it rapidly and uniformly over all its surface. The surface becomes rigid while the interior is capable of slight flow; as a result strains are set up between the two portions and the surface is left under compression which must be overcome before the glass can be broken by putting the surface into tension. When such glass is fractured the glass flies into minute, powdery fragments owing to the release of the strains. These may cause scratches but no slashing cuts. It is used for the windscreens of motor cars.

### *General domestic and illuminating glassware*

Manufacturers of domestic and illuminating glassware are to be found in each of the important glassmaking areas. Of the domestic glassware there

are three main types, namely, the purely hand-made English crystal glassware, plain, cut or engraved; glassware formed by pressing in a mould by a semi-automatic press; and mould-blown glassware which may be made from a lead or from a lime glass. The English lead crystal-glass, prepared from raw materials of high purity, has long maintained a high reputation on the world markets. All three sections of this domestic glass industry have had much foreign competition to meet for much domestic glassware has been imported into this country. Since labour costs enter largely into its production, lower-wage countries such as Belgium, Czechoslovakia, Poland and to some extent Germany, have had considerable advantages, but conservatism, both among workpeople and manufacturers, due to tariff discouragements, has also played its part. In the cheaper glassware, considerable progress was being made in the decade before World War II by the use of fully automatic machinery of various types for tumblers, dishes and the like; and there is little doubt that in the post-war period automatic machinery will again be utilised more extensively. The tendency for automatic machinery to displace hand labour in certain lines was also to be noted in Belgium and Czechoslovakia. What has been said about domestic glassware applies in large measure also to many forms of illuminating glassware, particularly lamp shades and reflecting bowls; and here there is an opportunity for an organised effort to meet foreign competition.

*Electrical glassware*

The modern creation of electrical glassware goes back only to World War I. Before 1914, 4,000,000 electric light bulbs per annum represented the highest output, only a small fraction of the total required, and the industry had greatly to be stimulated during 1914–18. Many types and sizes of bulbs were then needed. In more recent times, radio valve envelopes, cathode ray tubes, X-ray tubes, special glass bulbs for sodium-vapour lamps, high pressure mercury-vapour lamps and tubing for neon sign and fluorescent lighting have led to a great expansion in demands for electrical glassware. Since 1919 this country has in these respects kept abreast of other advanced countries; and, in regard to the mass production of the common sizes of electric light bulbs, was the first of the European countries to instal American automatic machines. The 24-arm Westlake machine and its later modification, the Ivanhoe, with a capacity of 75,000–100,000 bulbs per day were installed and were followed by the Ohio machine with a production of 150,000 bulbs per day. The Corning No. 399 (ribbon) machine, with a capacity of upwards of half a million a day, which has been in operation now some 15 or 16 years in the U.S.A., has generally been regarded as too productive for European requirements, but its employment here is not beyond the bounds of possibility.

*Chemical and heat-resisting glassware*

On the outbreak of World War I this country was in a serious position owing to the lack of chemical and scientific glassware which previously had been imported from Germany. Before 1870 we made our own scientific glassware from lead glass, but after the Franco-Prussian war alkali-lime and other glasses were imported from Germany and Austria. A new industry had to be created during World War I and this was largely made possible by the work of Sir Herbert Jackson in conjunction with the Institute of Chemistry and Messrs. Wood Brothers, and by Professor M. W. Travers who was responsible for Duroglass for Messrs. Baird and Tatlock. Messrs. J. Moncrieff were also active in the new section of the industry. Since that date this country has manufactured a range of chemical glassware of the highest quality.

Three of the varieties have a high silica content (about 80 per cent) and boric oxide content (about 12 per cent) and therefore also have low thermal expansion co-efficients and consequently also high thermal endurance. They are, accordingly, used for many purposes where heat resistance is desirable, not only for numerous scientific and illuminating purposes but also for cooking glassware. Other glasses of low thermal expansion and high softening point are made for high pressure mercury-vapour lamps, for sealing to tungsten and molybdenum and a variety of other purposes. Glass of high chemical and heat resistance is now being used extensively in this country on the industrial scale for pipe-lines for the conveyance of beverages and of corrosive liquids (strong acids) and also in condensing installations.

*Optical glass*

Although the production of optical glass does not compare in bulk with the sections of the industry already mentioned, it is the most important of all from a defence point of view. Many instruments of precision used by the three Fighting Services are dependent on optical glass for their efficiency. For use in such instruments the glass employed must be thoroughly homogeneous, free from bubbles and colourless in itself without the presence of any of the so-called 'decolourisers' used in many kinds of glass, for they achieve their purpose by selective absorption of light. This standard of excellence requires extreme care in the selection and purification of the raw materials and in the preparation of the melting crucibles; whilst the melting operations are more elaborate since they involve continuous stirring of the glass for many hours, followed by slow cooling. From the 16th to the 19th centuries increase in the size of telescopes was held up because of the impossibility of obtaining lenses of sufficiently good glass in the size required. The

modern technique for making high quality glass for optical instruments was worked out by P. L. Guinand, a Swiss clock and watchmaker, in 1790. Some of the ideas developed in his glass technique came to him from his experience in casting bells for his chiming clocks. He worked for a time with Fraunhofer in Bavaria but the benefits of his work did not become known in this country until some 50 years later. In 1824 the Royal Society set up a committee to deal with the problems of making improvements in glass for optical instruments, and between 1825–1830 Faraday did a considerable amount of experimental work on lead glasses containing boric oxide and on methods for obtaining glass free from bubbles. Much small scale work was also done from 1834 onwards by W. V. Harcourt on the relations between the optical and chemical properties of glasses.

This early work was known to O. Schott when in 1880 and onwards he, working with E. Abbé and the Zeiss brothers, began far-reaching experiments on the composition and properties of optical glasses, which led to the commercial production of a number of new types. Their efforts were backed by financial assistance from the German Government with the result that Jena optical glasses, as well as chemical heat-resisting and other scientific glassware, achieved a world-wide reputation and both British and French optical glasses fell into decline. At the outbreak of World War I Messrs. Chance Bros., the only British firm in this section of the industry, who had started the manufacture of optical glass in 1848 with the collaboration of the French glass technician Georges Bontemps, listed only 26 types in their catalogue. Immediate steps were taken to remedy the position and to meet with success the heavy demands made by that war. In 1917 the Derby Crown Optical Glass Company was established by Messrs. Wood Brothers and was turning out substantial quantities of optical glass before the close of the war. Shortly afterwards Sir Charles Parsons took over the works and the business was later incorporated in Messrs. Chance Brothers.

While experiencing very considerable difficulties in the early inter-war period owing to the collapse in demand and competition due largely to depreciated foreign currencies, a continuous policy of research and development was pursued with the co-operation of the British Scientific Instrument Research Association. From 1932 onwards the Service Departments took an active interest in optical glass research, with the result that the quality of optical glass produced in this country as estimated by homogeneity, isotropy and transparency, reached at least as high a standard of excellence as that achieved by any other country; and the range of optical glasses was progressively expanded as the results of the researches were incorporated in them. Soon after the outbreak of World War II a large deposit of very pure sand at Loch Aline in West Scotland

was developed. Portions of this sand, in which the iron oxide content can be brought down to 0·005 per cent, are now used to replace German sand previously imported. As a result this country has at hand a material purer than any other country in the world. Thus on the outbreak of World War II this country was in an exceptionally favourable position to meet the enormously increased demands made by the Fighting Services. In addition, Messrs. Chance Brothers were able to give technical assistance to Canada in setting up an optical glass industry in that Dominion and to furnish optical glass to other parts of the Empire and to the Allied Nations. These facts need emphasising for there is still an erroneous belief in this country that the best optical glass can be obtained only from Germany.

### *Glass fibres and fibre products*

Glass can be drawn into fine short fibres and in this form is used as packing for filtering air, heat insulation, and sound absorption. It can also be drawn into long filaments to form a twisted and spun yarn like cotton and linen. The filaments are of no greater diameter than two to three ten-thousandths of an inch and can be woven into tapes and cloths, or used for covering wire. As fabrics they are used as filtercloths in chemical manufacture and in many other ways; they are particularly well suited as electrical insulating fabrics and since they withstand higher temperatures than those of cotton or other organic fabrics, motors insulated by them can be run at a greater overload without risk of insulation breakdown. Continuous filaments of this nature withstand very high tensions and have been used as fishing lines, though chafing tends to make them rather short-lived. When laminated with low temperature synthetic resins, glass fibre furnishes a material lighter than aluminium and with superior mechanical properties. Although glass threads have been made for many centuries, the manufacture of fine fibres on a large scale is essentially modern. Three firms are engaged in this country in this field of manufacture.

### *Technical training and co-operative research*

Before 1914, scarcely a dozen graduates could be found as scientific workers in the glass industry. In 1915, the University of Sheffield founded the Department of Glass Technology, the pioneer institution of its type, to provide courses of instruction and research. It became in due course the central testing and research station supported by the whole industry. Many of its students have reached directing or other responsible positions. The Society of Glass Technology, also a pioneer in this subject, was founded in 1916 and through the standard of its

Journal rapidly acquired a large international membership. It has in fact led the way in international meetings of glass technologists, ultimately resulting in a full International Congress. These two institutions have established an important place for Great Britain amongst glass-producing countries, as well as assisting in the spread of technical knowledge so that the industry of the country has been able to cope with any problems relating to glass during World War II.

## CHAPTER II

# INTERNAL COMBUSTION ENGINES

### *Scope of the industry*

The internal combustion engine industry as represented by the membership of the Internal Combustion Engine Manufacturers' Association, includes stationary land engines, portable engines, marine auxiliary engines and marine propulsion engines up to 1,500 brake horsepower; also internal combustion locomotive engines.

The formation of the Association at the beginning of World War II, was a development of an earlier group of manufacturers of vertical internal combustion engines of the stationary type, formed to consider problems in connexion with terms and conditions of contract. The work of this group in bringing manufacturers together to discuss problems of the industry, was found to be advantageous, and encouraged the formation of the Internal Combustion Engine Manufacturers' Association, covering the wider range of engines.

Internal combustion engines for the motor industry, for the aircraft industry and large sized marine engines, have all followed specialised directions, largely due to the particular requirements of these industries. Their development and production are touched upon elsewhere. In the motor vehicle industry there are different limitations of space and weight, and even when engines of the Diesel type are employed, they are not expected to use the very heavy fuels which engines of the stationary type are frequently required to burn. Engines for aircraft have quite special conditions to meet, and operate with higher grade fuel than is normally available for motor vehicles. Extreme lightness of the weight-power ratio is a first consideration, and whilst reliability is of great importance, continued operation without attention over long periods, such as is required in stationary engines at waterworks and in many industries, is not a condition. The weight of an aircraft engine may be the same as that of an omnibus engine, but its power may be 10 times greater.

### *Evolution of the industry*

The origin of the internal combustion engine cannot be credited to any one man, and its wide variety of forms has been gradually evolved. The industry as defined is of recent growth and dates from the last decade of the 19th century. Each of the sub-sections mentioned has been developed to meet the different requirements and to use different

fuels, including non-vapourizable oils ignited wholly or partly by heat of compression, vaporisable oils with electric ignition, or gas of various kinds, such as town-gas, producer-gas and sewage-gas. In consequence of the many differences, the problems which arise in research and production are very varied.

Mass production of stationary land engines, except in small sizes, has not so far been found practicable on a large scale, owing to the need for supplying engines of very wide ranges of power and speed for direct connexion to dynamos, to many kinds of pumps and machines, as well as for driving them by belt or gearing. Engines needed for the propulsion of large motorships also have to meet varied conditions, and consequently have embodied many special features. The use of internal combustion engines for railway purposes has increased in recent years, but their first manufacture for this purpose dates back to 1918.

*The 'Diesel' engine*

On the continent all oil engines are termed 'Diesel', and the term has been particularly applied in the past in this country to a variety of forms, especially to high speed multi-cylinder engines used for transport vehicles and locomotives. The wide use of the name 'Diesel' neglects the fact that the ideas described in Diesel's early patents had, with one exception, to be abandoned before a commercially successful engine was developed. But a very important one remained valid, namely, compression to a sufficiently high degree to give a temperature which would ignite fuel sprayed into the cylinder without the use of any external heating device.

Another pioneer in the field was Akroyd Stuart who in 1890–91 experimented with tube ignition, and in 1892 applied for a patent for improvement of an engine burning heavy fuel. This occurred at the same time as Diesel applied in Germany for his patent, which only found commercial expression five years later. It may be said that Diesel pioneered the carrying of compression to a sufficient extent to cause spontaneous ignition of fuel sprayed into the cylinder without the help of any external heated surfaces, the fuel being sprayed in by means of compressed air; whilst Akroyd Stuart effected the spraying of the fuel by direct pump action at a lower compression ratio but with the addition of external heating.

The number of firms manufacturing internal combustion engines in this country has largely increased during recent years, and the export trade of the industry has also grown. Before 1914 it was only modest in amount, and as a consequence of war it almost disappeared between the years 1914–19. Thereafter it revived until in 1938 the export trade

exceeded 60 per cent of the total production, and this apart from the export of auxiliary parts, equipment and machinery required for running the gear produced by other industries.

The industry has established one of the latest formed Research Associations, and has acquired premises for laboratories at Slough where it will soon be in active work helping to strengthen the progressive work of its members by co-operative research, to which practically all the companies in the trade will contribute.

# CHAPTER 12

# LEATHER

*Uses of leather*

Leather, a material which has both toughness and durability, was used for making clothing for early man after exposing hides to smoke or rubbing in fats to give the skins pliability and a power of resisting the elements. Later vegetable materials were used such as bark, leaves and wood containing astringent substances collectively known as 'tannins'.

Today the great bulk of leather production goes into footwear and the making of numberless articles of general utility. It also plays an important role in the present mechanical age in transmitting power in connexion with machinery, e.g. belting leather; to convey material in continuous processes, e.g. in most spinning machinery; to insulate oil or water, e.g. as washers in pumps, rams, etc.; to provide a resilient cover for special parts of machinery, e.g. for rollers used in the cotton industry, as valves in gas stoves and as diaphragms in gas meters.

Leather is also used for decorative purposes for bookbinding, wallets and numerous fancy articles and has even been used for wall covering as a sound insulator. The hides and skins of domestic animals, the ox, the goat, the sheep and the pig are the chief sources of leather but the skins of wild animals, including reptiles, and to a small extent fish, are also used.

*Initial manufacturing processes*

The making of leather is possibly the most ancient of the crafts and in the course of ages much technical knowledge of it has been accumulated. But recently applied science has done more to establish the best way of processing the raw material so as to achieve a standard output suited for the particular purpose required.

The preservation of hides and skins from bacterial attack in the interval that elapses between slaughter and delivery at the tannery has received much attention, since perfect leather cannot be made from a bacterially damaged hide. Similarly flaying of the hide from the carcase has been studied and the process adopted at the abattoirs has been improved by the efforts of the Hide Improvement Society.

Hides and skins have to be prepared for tanning by a process which removes not only the hair on the outer surface of the hide but also the soluble proteins between the hide fibres so as to clear the interfibrillary

channels for the entrance of the tans, many of which are colloidal. In olden days hides used to lie in weak lime suspensions for nearly a year, but a study of the chemical factors involved has shown that a certain degree of alkalinity and the presence of a reducing agent are both necessary to remove the hair. Lime suspensions 'sharpened' with sodium sulphide are now in general use and dehairing is generally complete in a few days. For light skins required for fine-grained leathers arsenic sulphide has been popular, but owing to its obvious disadvantages as an industrial chemical, other reagents have been sought to produce the same effect. Calcium and sodium hydrosulphides have been successfully tried and in America dimethylamine is in commercial use. These milder reagents give a cleaner pelt and cause less damage to the hair. With sheep skins, in which it is important to remove the wool undamaged, experiments have been made to de-wool by the action of the proteolytic enzymes of fungi. The pancreatic enzymes have also been the basis of a successful de-hairing process.

A process of great antiquity for cleaning and softening the pelt before tanning is the bating process. This has now been investigated scientifically. Bating used to consist in treating pelts with an infusion of bird dung or dog dung, but it was found by the work of J. T. Wood that the essential element was the enzyme trypsin and synthetic bates have since been used.

*Tanning*

The tanning process consists in converting the hide or skin into a product which will not be putrescible and will possess the special properties of the particular type of leather desired. In the case of sole-leather (and many other leathers) this is done by treating the hide freed from hair, fat and flesh matter, with solutions of vegetable tanning materials. These combine with the main constituent fibres of the cleansed and prepared hide, known as 'collagen' fibres, to produce leather. The vegetable tanning materials used are chiefly mimosa bark, oak bark, valonia (acorn cups and acorns), myrobalans (a wild fruit), sumach (leaves), gambier (leaves and twigs), oak (wood), chestnut (wood) and quebracho (wood). The natural tanning materials are bulky in nature, and contain much useless fibrous material. The valuable constituents are extracted with water sometimes in this country and sometimes in the country of origin and the infusions concentrated down to treacle-like liquids or to solids to be marketed in this standard form.

Tanning of hides and skins by vegetable material is by no means the only process used. An important tannage today, used for the bulk of shoe-upper leather, is chrome tanning. This was patented by Knapp in 1858 and introduced into this country in 1879. Box and willow calf,

glazed kid, suede for shoes and gloves and for many leathers are now made by this process, which consists in using a solution of a basic chrome salt and precipitating a 'chrome complex' on the fibre. The special features of chrome-tanning are that it produces thin leathers of great strength and that they can withstand high temperatures in water.

Other mineral tannages are iron tannage, studied largely in Germany, and zirconium tannage for the production of white leather which is beginning to make headway in America. Alum tannage (generally known as 'tawing') is one of the oldest leather-producing methods known. Alum-tawed leather combines stretch with great tensile strength and in consequence is largely used for making gloves. It is also used for dressing fur skins. It has the disadvantage of not being water-resistant. Another old process is oil tanning, in which cod oil is generally used today, e.g. for chamois leather. Synthetic tannins have also been prepared by the condensation of phenol-sulphonic acids which since their first preparation in 1913 by Dr. E. Stiasny, are making considerable progress.

### *Finishing*

The advances made in the production of dyes from coal-tar have greatly assisted the leather dyer; while the oil industry has produced sulphated oils which are of use in the 'fat liquoring' of leather, i.e. the lubrication of its fibres. The use of cellulose lacquers, the development of water-pigment (casein) finishes and the use of plastics are all recent advances in scientific knowledge which are now employed in leather finishing.

### *Scientific agencies*

During the last half century, and more particularly the last thirty years, leather manufacture has been subjected to increasing scientific control. All tanneries of importance now have leather chemists on their staffs. This advance was mainly due in the first instance to H. R. Proctor, who was appointed in 1891 professor of the Department of Leather Industries at the Yorkshire College, later the University of Leeds. Subsequently, in 1909, the Leathersellers' Technical College, replacing the earlier Herold's Institute, was founded in London. At these institutions the technical education of personnel for the industry has been advanced and extended. Classes in leather chemistry and technology have also been established at the Northampton Technical College and at the Manchester College of Technology. From these centres the industry both here and abroad has been supplied with trained staff.

There are other agencies for the scientific welfare of the industry. The International Society of Leather Trades Chemists was formed in

1897 in London at the instigation of Prof. Proctor, A. Seymour-Jones, J. T. Wood and J. Gordon Parker with the support of prominent continental trade chemists. As a result, reliable methods of analysis have been drawn up and research work encouraged by meetings and discussions and by records of progress in its journal.

*Co-operative research*

The trade itself took steps for fostering scientific research by the formation in 1920, with Sir Robert Pickard as its first Director, of the British Leather Manufacturers' Research Association, where long-range investigations have been carried out, as well as work of more immediate interest. The Association has concentrated on studying the scientific basis of leather-producing processes in use in this country and has carried out pioneer work in analysing the physical properties of various classes of leather, with a view to their ultimate use. Work on vegetable tanning has shown the great importance of the balance of natural acids and organic salts in controlling the character of the natural tanning materials. This work has shown incidentally how best to substitute one tanning material by another in times of scarcity. Similar work on chrome-tanning has dealt with the effect of organic acids (known as 'masking' substances) on the character of the leather produced when introduced into the chrome tanning 'complex'. Work on the physical constants of the oils used has also shown how the favoured oils of pre-war days could be satisfactorily replaced by the suitable blending of alternative materials.

Book-binding and upholstery leathers made within the last thirty years are peculiarly liable to 'acid rot' owing to the absorption of acid from the air of industrial towns. The leather gradually deteriorates and eventually crumbles to a powder. Investigations by the Research Association showed that the harmful effect of the acid could be counteracted by the incorporation of certain salts in the leather, and specially prepared 'protected' leathers are now available, which ensure a much longer life to bindings and upholstery.

An important feature of the Association's programme is the conduct of investigations at the works of member firms by the scientific staff of the Association in close collaboration with the firm concerned. The results are made generally available to the industry.

*Structure of the Industry*

The industry, owing to its history, is largely in the hands of firms of long standing, most of them conducted as private companies. The industry is a fairly large one, and the following brief statistics show its main distribution.

GROSS OUTPUT (£'000)

| | *Fellmongery* | *Tanning and dressing* | *Harness, saddlery and leather goods* |
|---|---|---|---|
| 1924 | 4,718 | 32,215 | 5,112 |
| 1930 | 3,186 | 27,792 | 5,002 |
| 1935 | 2,652 | 26,032 | 5,676 |

# CHAPTER 13

# METAL INDUSTRIES

## IRONFOUNDING

*Nature and forms of cast iron*

The ironfounding industry is concerned with the manufacture of products in iron which are used in the cast form, either in grey iron, which can be machined, but is not malleable in the cold state, or in white iron, which is hard and brittle. White iron is also the first step towards the manufacture of malleable cast iron for, by an annealing process, it can be made ductile. All cast irons are alloys of iron and carbon, containing more carbon than the steels, and are not usefully forgeable. In grey cast iron, the bulk of the carbon exists in the form of graphite, and in white cast iron the whole of it is in the form of iron carbide.

*Historical*

The manufacture of cast iron certainly antedates the Christian era and literary evidence suggests that it was practised in China several centuries B.C. One of the largest iron castings in existence is a lion 20 ft. high and 18 ft. long. This dates back to A.D. 953 and is to be found about 50 miles south of Tientsin. There is some reason to believe that the Greeks were familiar with it in the 6th century B.C. In Western Europe, early iron-making operations were directed towards producing a 'bloom' of malleable and relatively impure metal, in the form of a solid pasty mass. In a simple hearth or furnace with primitive bellows, a rich ore and charcoal fuel can be made to yield such material at a comparatively low temperature. Only when primitive furnaces became larger and bellows improved did it become possible, as a result of the higher temperature reached, to produce the molten alloy of iron and carbon, the latter derived from the fuel used. The molten metal could then be cast into moulds and used in that form, or could be refined to wrought iron and later to steel.

There is little doubt that cast iron was often a partial and accidental product of the primitive process and that the art of its manufacture has been discovered and re-discovered by many peoples on many occasions. The modern blast furnace is the lineal descendant of these primitive furnaces and its product, pig iron (metallurgically a cast iron), is the raw material of the modern founder.

The industry originated in Western Europe in the 14th century. The presence of iron ore, water power from rivers, and charcoal fuel from its forests, led to the establishment of the industry in Sussex, chiefly for ordnance, for which those founders had a great reputation. The denudation of the forests led to a decline in output, until the industrial revolution in the 18th century created an enormous demand for iron, satisfied by the use in blast furnaces of coke made from coal. Improvements in the art of moulding were introduced by Abraham Darby, and he probably used coke as a blast-furnace fuel about 1713, although this discovery is often attributed to his son. The family was responsible for the erection of the first cast iron bridge at Coalbrookdale in 1779, in association with John Wilkinson who made, among many other articles, cast iron coffins and boats.

The availability of the new material as an alternative to timber and stone was of great assistance to engineers and the period of empirical development went on until 1830 when, chiefly through the work of Fairbairn and Hodgkinson, it became the subject of scientific study and deliberate experiment. As a building material, it began to be replaced by structural steel after 1855, but its use in industry, for public and domestic purposes, has continued to the present day.

*Founding*

Founding differs strikingly from all other engineering processes, and ironfounding has strong family resemblances both to steelfounding and the founding of brass, bronze and aluminium alloys. While traditionally a craft, involving the skilled arts of patternmaking, moulding and core making, ironfounding has in recent years been subjected to the impact of science by which a wide range of materials suitable for special service requirements has been produced, and great improvements have been made in moulding materials and melting methods. The industry has also been developed mechanically in ways which permit large numbers of castings of the same kind to be made by continuous or mass production methods. Iron castings in Great Britain are made to the extent of 2 to 3 million tons per annum, employing some 100,000 people, and operating in about 1,700 establishments; but roughly one-sixth of these produce two-thirds to three-fourths of the output. The castings are widely used in all industries, building, engineering, chemical, etc.; in transport, air, land and marine, and in domestic life where hollow-ware, stoves, grates, radiators, and baths are familiar objects. The material is cheap to produce and can be made with a variety of shapes and sections in one piece, close to the finished sizes. It lends itself to various finishing processes for decorative purposes, including electro-deposition and vitreous enamelling, and to treatments for heat-, corrosion- and wear-

resistance. From cast iron the engineer can produce articles ready for machining, without recourse to materials which have been through a long series of refining operations. Practically any size and weight can be produced in one piece, up to 200 ton anvil blocks and ingot moulds.

The metallurgical development of cast iron dates from about 1920, at which date 15 to 18 tons per square inch was an extremely good figure for its tensile strength. At the present time material is in commercial production having tensile strengths of the order of 40–45 tons per square inch. Among recent developments may be mentioned, apart from munitions products, the use of cast iron for engine crankshafts, camshafts and brakedrums; cast iron pipes, centrifugally cast up to lengths of 16 ft.; and blocks for roadways, such as the Mersey tunnel. Special cast irons can be made non-magnetic and also resistant to heat, corrosion and wear.

The invention of malleable cast iron is generally attributed to the French scientist Réaumur, 1683–1757, though it does not appear to have led to commercial developments. There is evidence, however, that the art was developed in England prior to this date. The traditional English process produces a material usually known as 'whiteheart malleable'; whereas the process developed in the United States, now also practised in this country, led to the production of the material known as 'blackheart.'

### *Moulding*

The foundry process consists essentially in preparing from the sample or drawing of the part to be made, a positive of similar size and shape, the pattern, and this is employed to produce a negative, the mould cavity. The mould material is usually sand or sometimes metal. The mould is made in parts to permit withdrawal of the pattern, and the cavity of the re-assembled mould is then filled with molten metal through suitably disposed channels. Hollow castings can be made by the insertion in the mould of a core, so that metal can only occupy the space between core and mould. After cooling, the mould is opened and the casting removed for use or for machining.

### *Co-operative research*

Owing to the scattered nature of the industry and the existence of a large number of small units, much of the research work is conducted by the British Cast Iron Research Association, incorporated in 1921. The Association, situated near Birmingham, has a branch at Falkirk which is a centre of the light castings section of the industry. The Association concerns itself not only with cast iron and malleable cast iron, their structure and properties, but also with the founding process,

including moulding materials and technique, melting furnaces and technique, and all auxiliary materials and methods used in the industry. It has done much to raise the technical status of the industry and the quality of the material, and to assist users of castings by the dissemination of information and advice, through reports on its research work and from other sources. The following are a few of its outstanding achievements previous to 1939:—(1) Contributions to the study of graphite formation and to methods of securing ultimate refining of graphite, and to the study of 'inclusions' in cast iron. (2) The establishment of properties requiring quantitative determination for the control of moulding sands and the evolution of testing equipment for determining strength and permeability. The examination of nation-wide deposits of moulding sands and core sands and the development of synthetic sands. (3) The establishment of methods of chemical analysis and mechanical testing, microscopic examination and physical testing, to facilitate control within the industry. (4) The elucidation of the cause of volume change, or growth, in cast iron at high temperatures and the consequent development of 'silal', 'nicrosilal' and 'cralfer' heat-resisting cast irons, and improvements in ordinary irons required to withstand high temperatures. (5) The standardisation of the design of the cupola furnace, universally used in the industry, and the development of the balanced blast cupola. The Association has designed and installed about 230 of this particular type of cupola furnace, including 50 overseas, capable of an aggregate hourly throughput of about 1,700 tons of molten metal. It is estimated that one-fifth of the cast iron made in Great Britain is poured from this type of furnace, and on a pre-war fuel cost the use of the new cupola yields an annual saving of £30,000.

## IRON AND STEEL

There is no major world industry that owes to Great Britain more in the way of scientific and technical advances than the iron and steel industry. 'In the steel industry every great invention had its origin in Great Britain.' That tribute was paid by Charles Schwab, probably the greatest iron master of the past generation and at the time the head of the greatest steel company in the world.

### *Historical*

The beginnings of the industry as we know it arose from the introduction by Darby of a method of smelting ore with coke instead of charcoal in pig iron production; a process of essential importance at the time owing to the dwindling timber resources of the country. The growth of the coal industry led to an increased demand for iron to make

mining machinery and the two industries became inter-dependent. Watt's invention in 1765 of the separate condenser for the steam engine also led to the rapid development of engineering practice which in turn necessitated more and better iron products. Some indication of the historical development of ironfounding has already been given, but iron and steel are so closely connected that some repetition of its essential features is necessary here.

Henry Cort developed the puddling process in 1784 and as a result iron was produced in a form easily forged and worked. The grooved rolling mill for making iron bars to replace the earlier mills was introduced by Cort in the same year. Iron rails, previously of cast iron in short lengths, then became possible on a large scale and led to Trevithick's locomotive in 1801 designed primarily for the mining industry. Stevenson's locomotive in 1814 naturally led to still further production for the larger transport demands that followed. Pig iron output in the hundred years following Darby's invention increased from 17,000 to over 1,000,000 tons per annum and that output was doubled in the next twenty-five years. The introduction by Neilson, in 1828, of the use of hot blast in the manufacture of pig iron led to a substantial reduction in fuel consumption with improved efficiency and increased output.

Much of the pig iron was used in the manufacture of wrought iron for purposes where easily forged and worked materials were required. The increasingly stringent demands, however, of the engineering industry necessitated a material having greater uniformity and superior physical properties. Steel was known: Huntsman in 1742 had made steel by the crucible process, but the product was expensive and it could not be made by the methods then available on the scale demanded by the engineering and transport industries.

*The Bessemer and Siemens-Martin processes*

In 1856, however, the Bessemer process was invented which altered the whole position, for steel previously costing £60 a ton was ultimately produced for £12. The Bessemer (acid) process progressed rapidly both here and in other iron-producing countries but, in 1864, the Siemens-Martin 'open hearth' process was invented and began to rival that of Bessemer. The combination of Siemens' regeneration furnace with Martin's metallurgical methods were the basis of this open hearth process which has now so largely replaced the Bessemer (converter) process.

The problem of dealing with iron ores containing phosphorus—a weakening constituent—still remained a major difficulty, especially for steel production from the continental phosphoric ores. The invention

by Thomas and Gilchrist in 1877 of the basic Bessemer process solved that particular trouble and led to an accelerated production of iron and steel in Germany, including Lorraine. To it may be attributed in large part the rise of Germany as a great industrial country. Great Britain, however, still retained technical and economic supremacy in iron and steel production until about 1890 when, for the first time, production in the United States exceeded that of Great Britain. From that date onwards, owing largely to the rapidly expanding home market in the U.S.A., the industry here has tended to lose technical predominance and developments in plant and machinery for improving output took place elsewhere, especially in America.

*Alloy steels*

In the production of alloy steels, so largely demanded by modern engineering practice, this country was also a pioneer. Faraday laid the foundation in 1819–24 by his researches on alloys of iron, especially for better cutting surfaces and non-corrodible metal for reflectors. In 1882, Dr. (later Sir) Robert Hadfield, when looking for a substitute for emery wheels, produced a steel containing up to 13 per cent of manganese. Its resistance to abrasion and its non-magnetic character are its essential properties and its introduction made possible rapid developments in crushing machinery, railway points and crossings and similar products requiring great resistance to external stresses. Hadfield's name is further associated with the development of silicon steel of great value for electrical purposes since, by reducing magnetic losses, it increased the efficiency of electric transformers and machinery generally, so making the application of electric power to industry economically possible. Another step forward in alloy steels had been the invention, in 1856, of air-hardening tool steel, by Robert Mushet, which owed its hardness to about 6 per cent of tungsten and to a high manganese and chromium content. High speed steel with 14 to 18 per cent of tungsten was made known in 1900 by the work of Taylor and White in America.

British metallurgy made another landmark by the discovery of stainless steel containing 12 to 14 per cent of chromium by Brearley in 1913. This steel, from which modern cutlery and other domestic articles are produced, and variations of it containing nickel and other elements, have been of great importance to the chemical and engineering industries where high resistance to corrosion is required. Other alloy steels containing varying proportions of carbon, nickel, chromium, molybdenum, vanadium, tungsten and cobalt have led to improvements in recent years in all forms of machine tools and high speed machinery, and they have been of much assistance in the evolution of the motor car and aeroplane. Considerable contributions were also made by other

British metallurgists. Lowthian Bell in 1872 worked out the theory of the blast furnace and Sorby's introduction of the microscope in the examination of steel in 1864 laid the foundations of metallography.

*Mechanisation*

This country was the birthplace of iron and steel technology, was its leader for 150 years, and is still in the van for alloy steels. But the development of industrial plant for the factory has made, in the last twenty-five years or so, greater strides in the U.S.A. and on the continent. The modern blast furnace as used in this country with a daily capacity of 1,000 tons, and its ancillary plants such as blowing engines, stoves, charging devices and the like, are American in design and construction. The continuous rolling mill is also largely American in origin, though due in part to British emigrants. Cluster rolling mills are a continental device and machinery from that source had to be acquired for carrying out reconstructions effected here in the inter-war period.

Fuel economy is of vital importance in this competitive industry and methods to that end were developed first on the continent; British practice rapidly followed. Even in steel making for general purposes plant such as the gas machine and the continuous charging machine are of American origin. The United States, with its large home market, felt the economic necessity of developing mass production methods and has made good use of its opportunities.

*Electric furnaces*

The electric furnace also, whilst owing its origin to the discovery of the carbon arc by Humphry Davy in 1800, followed by the patenting of electric furnaces operating on both the direct and alternating arc principle by Siemens in 1878, really originated in the work of Heroult who built the first commercial direct arc furnace in France in 1899. Electric furnace practice was largely adopted subsequently on the continent and in the United States but has received stimulus in this country from the production of alloy steels.

*Science on the directorates*

During the years following World War I, several of the leading British firms extended and strengthened their research and development departments; and, equally important, men of science began to find places on some of the boards of management. Today there are three fellows of the Royal Society on the boards of direction of leading firms.

*Co-operative research*

The industry took other progressive steps in this period. The National Federation of Iron and Steel Manufacturers, later to become the British Iron and Steel Federation, first appointed a Fuel Economy Committee in 1924 which was succeeded in 1929 by the Iron & Steel Industrial Research Council, associated with a number of organisations including the Iron & Steel Institute. That society has always been, since its foundation in 1869, the premier organisation devoted to the study of iron and steel technology and much of the scientific work of the new research body was carried out with its co-operation. The Iron & Steel Institute is international in membership and reputation.

The organisation of research adopted by this co-operative body, which has recently been re-constituted as the British Iron & Steel Research Association, differs from that of all the other Research Associations. There are no central laboratories and all the work has been organised through committees and conducted partly at works in the closest conjunction with their technical staffs and partly at the laboratories of universities and Government organisations. In this way, not only has intimate contact been maintained with existing practice but large contributions in kind have been made which have greatly exceeded in money value the subscriptions from industrial sources. A further feature of this organisation is that any specific research undertaken by a particular committee is placed in the laboratory where the most eminent scientists engaged in that field of research can undertake its direction and, by this means, the industry has secured the collaboration of every appropriate university research department in the country. Thus, there is no tendency for the research work to become stereotyped, since the latest developments of scientific thought and the impact of other work on which those directing the research are engaged can be brought to bear with great advantage to the industry. The new organisation, with a director of research, while preserving the essential features of the earlier scheme both in actual work and the application of results, will enable a wider field of research to be covered and bring about a more closely-knit programme.

It is only possible to refer briefly to some of the main lines followed by this important organisation to which the Iron & Steel Federation has undertaken to subscribe up to £250,000 a year as an essential activity of the industry. The work has been divided into three main sections. The first section has dealt with improvements in production practice and has been organised by committees on blast furnaces, open-hearth furnaces, rolling mills and refractory materials, together with regional coke committees. The success achieved has been materially assisted by periodic conferences attended by the managers of these

separate departments. As a result new methods have been devised and rapidly put into practice. Conversion from coal to coke has been improved and very large economies in coal consumption effected. As an illustration it can be said that, whereas the coal consumption per ton of finished steel was of the order of 4½ tons in 1924, by 1937 it had been reduced to less than 2½ tons.

The second section of work has dealt with the properties and qualities of iron and steel products by means of joint committees with the Iron & Steel Institute and with such subjects as heterogeneity of ingots, corrosion, alloy steels, steel castings and the chemistry and physics of steel-making generally. Here again, considerable successes have been achieved; the work on corrosion being of special importance.

The third section has been supervised by committees associated with various other bodies and has dealt with tin plate, structural steel, deep-drawing steels and steels for use at high temperatures. The efficiency of steam power plant in the last fifteen years has been marked and 29 per cent of the increased efficiency has been attributed to improved steel which has allowed higher steam pressures and temperatures to be used.

The following statistics are of interest as showing the gradual fluctuations of the industry here and in the United States and Germany:

PRODUCTION OF PIG IRON AND STEEL INGOTS IN UNITED KINGDOM ('000 TONS)

| Year | Pig iron | Steel ingots by processes: Converter acid | Converter basic | Open Hearth acid | Open Hearth basic | Electric (ingots and castings) | Total Steel |
|---|---|---|---|---|---|---|---|
| 1835 | 1,000 | | | | | | |
| 1855 | 3,218 | | | | | | |
| 1880 | 7,749 | 1,044 | | 250 | | | 1,295 |
| 1890 | 7,904 | 1,613 | 402 | 1,564 | | | 3,579 |
| 1900 | 8,959 | 1,253 | 491 | 3,156 | | | 4,900 |
| 1913 | 10,260 | 1,049 | 552 | 3,811 | 2,252 | | 7,664 |
| 1923 | 7,440 | 358 | 137 | 2,516 | 5,278 | 64 | 8,482 |
| 1931 | 3,772 | 113 | — | 1,155 | 3,777 | 53 | 5,202 |
| 1937 | 8,493 | 255 | 418 | 2,215 | 9,660 | 215 | 12,984 |

PRODUCTION OF PIG IRON AND STEEL INGOTS (ALL PROCESSES) IN GERMANY AND IN UNITED STATES ('000 TONS)

| Year | Germany | | United States | |
|---|---|---|---|---|
| | Pig iron | Steel ingots and castings | Pig iron | Steel ingots and castings |
| 1880 | 2,468 | | 3,835 | 1,247 |
| 1890 | 4,099 | 2,232 | 9,202 | 4,277 |
| 1900 | 7,549 | 6,645 | 13,789 | 10,188 |
| 1913 | 16,761 | 18,935 | 30,966 | 31,300 |
| 1923 | 4,936 | 6,305 | 40,361 | 44,943 |
| 1931 | 6,063 | 8,291 | 18,426 | 25,945 |
| 1937 | 15,958 | 19,848 | 37,127 | 50,568 |

## NON-FERROUS METALS

### *Metals concerned*

The metals known in early times were those which occurred native, such as gold, silver and copper; or those which were easily smelted from their ores, such as lead, tin and iron. The negative phrase 'non-ferrous metals' is used to describe the large number of known metals other than iron and is a relatively modern term.

The outstanding feature of non-ferrous metals is the high degree of permanence they possess. Not only do the precious metals possess this property but it applies to copper, tin and lead to a marked degree. The fine bronze vessels of China, dating hundreds of centuries B.C., are notable examples; and the non-ferrous metallurgical skill of the early civilisations of the near East and of the Greeks and Romans is well known.

The chief non-ferrous metals used in industry are copper, tin, zinc, lead, aluminium, nickel and magnesium. The world output of these metals in 1938 ranged from over 2 million tons of copper, nearly 1¾ million tons of lead, about 1½ million tons of zinc, rather more than ½ million tons of aluminium and less than ¼ million tons of tin and nickel. Production of magnesium before World War II was small, but expanded greatly during it : magnesium will be available in considerable quantities in the post-war period. Other metals used in making alloys, mainly with steel, are chromium, tungsten, cobalt, manganese, beryllium, arsenic, cadmium and vanadium. In addition there are the precious metals of which platinum is used not only for jewellery but for chemical ware. These various metals and the alloys derived from them are the

bases of a number of industries each having problems of its own, and they are grouped in a series of distinct trade organisations.

The metals in a pure condition are relatively little used, though the tonnage of copper used for electrical purposes and of lead for building, and other industries, is very considerable. Where mechanical strength is important, the pure metals are inferior to alloys, for by the admixture of different metals high strength can be obtained without serious loss of, and in some cases with increased, resistance to corrosion. The alloys of non-ferrous metals with steel have been dealt with, and in this section alloys will be understood to include only the more or less close admixture of two or more non-ferrous metals. During the 19th century, and especially towards its close, the science of metallurgy made great progress. New methods of production and fabrication came into use. Aluminium and magnesium for instance ceased to be scientific curiosities and within the half-century became important industrial materials.

The sub-sections of the industry have developed differently. In the use of copper and tin, for example, there was much historical tradition; and metallurgical skill in their manipulation had reached a high standard before scientific research was widely applied. In their case science has explained why traditional practice has proved so successful. In other sections such as those of the light alloys, success has been due to research from the outset.

*Refining*

Improvement in refining methods has led to the marketing of large quantities of some of the main non-ferrous metals in a high degree of purity. Copper, for instance, is available with less than one part in two thousand of impurities, while lead of a still higher purity is a common article of commerce. This greater purity gives the metallurgist a closer control of the metal and of any alloys he wishes to produce. In the course of these manipulations it has been found that the alloys made previously from less pure materials were sometimes superior in properties to those made from purer constituents. Impurities that had been removed had then to be put back again under controlled conditions. For instance it is now known that $\frac{1}{20}$th of 1 per cent of silver has a profound effect in raising the temperature at which cold-worked copper softens on annealing; and that the electrical conductivity of copper is very dependent on high purity, though different impurities affect conductivity and mechanical properties in varying degrees.

*Casting*

The casting of metals and alloys is a starting point in most metallurgical manufactures. The quality of wrought metals, i.e. sheets, tubes,

wire, etc., depends largely on the quality of the cast ingot or billet. The facility with which metals can be cast to intricate shapes is of great manufacturing importance but it is equally vital that the casting should be of high quality. Not only must the surfaces of the casting be smooth, but internal holes, sponginess and non-metallic inclusions must be avoided. The founder who is responsible for making castings is confronted with two major difficulties, first the tendency of molten metals to dissolve certain gases, particularly hydrogen; and next the change in volume which occurs when nearly all metals change from the molten to the solid condition. The development of foundry control, based on a knowledge of the behaviour of metals and alloys in these respects, has been the elimination of harmful dissolved gases from the molten metal before casting and the control of pouring practice to enable the volume change on solidification to be counteracted by feeding in fresh liquid metal to prevent the formation of internal voids. The metals and alloys all have their special characteristics and present different problems to the founder, who must be familiar with a wide range of technique based upon investigations into the scientific behaviour of his materials.

### *Powder metallurgy*

Powder metallurgy has been developed considerably in recent years. It is not necessary always to start with molten metal, and metal components may be made from powder. The metal powder is usually made by reduction of the metal oxide or other suitable chemical compound. This metal powder is then pressed together and the resulting block heated to a point below that of melting so that the particles are bound together by a process known as sintering. This technique is especially valuable in the case of metals with very high melting points. The briquette so formed, with or without further operations upon it, is sufficiently ductile to be drawn into wire or other form. Metal powders are also used with non-metallic powders, such as carbides, for hard die materials. In these cases the non-metallic particles are cemented together by the metal by heating at a temperature above its melting point. Cobalt is the most commonly used cementing metal.

Another development is the use of powdered alloys for bearings. The porosity can be controlled and, if such a porous bearing after heating is quenched in oil, a certain quantity is absorbed to provide lubrication; or graphite can be incorporated to serve a like purpose.

### *Precipitation hardening*

One of the outstanding metallurgical discoveries of the present century is 'precipitation-hardening'. The hardening of steel at a high

temperature by quenching in water or oil has been known for a long time. In the non-ferrous metals industry a corresponding increase in strength and hardness can be achieved by heating certain alloys to a relatively low temperature or by quenching them in water and subsequently allowing them to stand at room temperature. The alloy hardens by the precipitation of some constituent in the structure of the metal, which is in solution at a higher temperature, a phenomenon referred to generally as precipitation-hardening, but if it occurs at room temperature it is known as 'age-hardening'. Age-hardening was first discovered by Wilm in an alloy of aluminium subsequently called 'Duralumin'. Precipitation-hardening gives many alloys greatly improved mechanical properties and the age-hardening of aluminium alloys has been of special importance in the aircraft industry. Other alloys so treated are beryllium-copper, copper-chromium, aluminium-magnesium, copper-nickel-aluminium, and lead-antimony to name but a few. As an example of increased strength, the tensile strength of beryllium-copper is increased from about 30 tons per sq. in. to about 75 tons per sq. in. in the annealed precipitation-hardened condition.

### *Alloys*

Two-thirds of the known elements are metals and the alloys that can be made by mixing two, three, four or more of them together are legion. New variants are devised to find an alloy suitable for a specific purpose, either to find a cheaper material that will serve as well as that previously employed or, more usually, to find one which has improved properties. When the practical requirements are known the quest begins. The development of the magnesium alloys is a case in point. The lightness of magnesium obviously directed attention to it for aircraft purposes; its alloys were accordingly examined and have proved very useful.

The production of lead alloys for cable sheathing is another example. The metal itself was liable to crack under alternating stresses and an alloy was required with a good resistance to fatigue. A series of ternary lead alloys with greatly improved fatigue-resistance was devised as a result of research by the British Non-Ferrous Metals Research Association which has proved very valuable, not only for submarine cables, but for cables on ships of war and for lead water-pipes.

The search for new alloys has been assisted materially by examination of the internal structure of metals and alloys by means of X-rays and by the electron microscope. In these ways not only is the crystal nature of metals displayed but the X-rays reveal the minute details of the crystal structure.

*Corrosion resistance*

The high degree of resistance to corrosion shown by the non-ferrous metals has already been mentioned and much work has been done upon the subject. The resistance of the copper alloys to atmospheric and salt water corrosion is well-known and the use of zinc as a covering to steel by the galvanizing process is equally familiar. The aluminium alloys have a high degree of corrosion resistance and are much used in chemical plant.

Originally resistance to corrosion was regarded as an intrinsic property. The immunity of gold, for instance, was well-known. Research work conducted by the British Non-Ferrous Metals Research Association shortly after World War I threw a new light on corrosion-resistance in non-ferrous metals and established the fact that the freedom from attack was brought about by the formation of a thin, and in some cases a transparent, surface-film of the product of corrosion which was so complete and free from porosity as to protect the underlying metal. The statue of Eros in Piccadilly Circus was cast in aluminium at a time when but little was known of the metal and its alloys but it weathered with much success. Similarly aluminium is used for chemical containers with a thin film of aluminium oxide, rapidly formed on exposure to air, which seals the metal off from attack. The resistance to corrosion of stainless steel is due to the formation of thin transparent films consisting primarily of oxides of chromium which protect the underlying steel.

The search for corrosion-resistant metals and alloys has involved a study of these films and the rate at which they re-form if they are locally damaged by mechanical or other means. Great advances have been made in this, and the study of the corrosion of metals and alloys by sea water has been shown that the protective film is all-important. The successful aluminium-brass alloy for condenser tubes is due to the impervious nature of an easily formed surface-film containing aluminium oxide. Aluminium bronzes are similarly successful against corrosion. Sometimes the film formed is thick and visible as in the case of the green patina on exposed copper; and it is this patina or film that protects the underlying metal. The study of these protective films requires highly specialised knowledge and technique though the results may be expressed in a simple prescription to the user.

The importance of finding means to prevent corrosion is shown by the fact that losses from it in the metallurgical industries have been computed at about 500 million sterling per annum, and although the proportion of this loss occurring in the non-ferrous industries may be small it is important in total. Valuable research work on corrosion was initiated by the Institute of Metals and has since been done at the Chemical Research Laboratory of the Department of Scientific and

Industrial Research. Cambridge University as well as the British Non-Ferrous Metals Research Association have done notable work on the subject.

*Soldering and brazing*

The mechanical processes employed in the non-ferrous metals industry have also been much improved as a result of scientific investigation. The chief ways of jointing metals are by soldering, brazing and welding. Soldering and brazing are similar processes consisting of joining two pieces of metal together with an alloy having a lower melting point than the metal to be joined. The molten alloy is run into the joint and on solidifying holds the two pieces together. Soldering is carried out with lower melting-point alloys than brazing. During World War II investigation has been directed to find means to cut down the tin content of solders and to find new and suitable solders. The process of welding is dealt with elsewhere (p. 103).

*Co-operative research*

A number of the leading firms in the industry have scientific departments to explore the problems that confront them and a large proportion of them are members of the British Non-Ferrous Metals Research Association which was formed in 1920. At the outset the Association conducted its work extra-murally, but soon established its own laboratory in the University of Birmingham. When extensions were called for, premises were acquired in London near Euston Station. These have been greatly enlarged and new buildings on a contiguous site erected. The Association is one of the most successful of these co-operative organisations, and a considerable extension of its financial resources is in prospect. It hopes shortly to be operating on an annual budget of about £100,000. One or two instances of its achievements have already been cited. Perhaps its chief contributions to the industry have been the comprehensive study of some of the main fields of scientific importance to the industry. Thus a complete investigation of the processes of casting brass ingots was undertaken and published as a monograph. Although directed primarily to brass ingots, many of the results are applicable to castings of metal and alloys in general. A similar wide study has been made of sand-cast shapes, with information of gas reactions and their avoidance, together with methods of feeding to eliminate shrinkage and porosity.

Mention must also be made of the British section of the International Tin Research and Development Council formed in 1932. This Council consists of delegates appointed by the Governments of the principal tin-producing countries, and was set up for the purpose of acquiring

and disseminating scientific knowledge relating to tin, its alloys and chemical compounds and to the processes involved in their production and applications. The researches undertaken have as their object the discovery and development of new industrial applications of tin and the improvement of existing products and processes.

The British section of this international organisation established laboratories at Greenford, Middlesex, shortly before the outbreak of World War II, and a wide series of investigations has been undertaken dealing with tin-plate and canning, electro-deposition of tin, improved tin alloys especially for use as bearing metals for internal combustion engines, and with methods for enhanced resistance of tin alloys and compounds to wear and corrosion generally. The organisation in its lay-out and objects is not unlike that of the Rubber Producers' organisation, the British section of which is referred to on p. 156.

### *Size of the industry*

The following brief statistics give an indication of the size of the main sections of the industry between the years 1924 and 1935.

| (1) | *Gross Output* (2) (£'000) | | | *Cost of materials used and amount paid out.* (3) (£'000) | | | *Net Output* (4) *excess of* (2) *over* (3) (£'000) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1924 | 1930 | 1935 | 1924 | 1930 | 1935 | | | |
| Copper and brass (smelting and rolling) | 22916 | 20994 | 21343 | 16788 | 15174 | 14316 | 6128 | 5820 | 7027 |
| Aluminium, lead and tin (smelting and rolling) | 31760 | 26539 | 33249 | 25234 | 20353 | 23476 | 6526 | 6184 | 9773 |
| Finished brass | 10165 | 10730 | 11542 | 4398 | 5011 | 4787 | 5767 | 5719 | 6755 |
| Gold and silver | 15796 | 8095 | 31182 | 14811 | 7036 | 30155 | 985 | 1059 | 1027 |
| Plate and jewellery | 10962 | 8706 | 9194 | 5508 | 4105 | 4577 | 5454 | 4601 | 4617 |

## WELDING

Welding is hardly an industry; it is a process used in all branches of engineering construction, and the beneficiaries from research on it are the users of welded material rather than the suppliers of the necessary equipment.

### *Early stages*

The development of the various processes of welding date from 1880–1900 but their application on a large scale in this country began during World War I. Before 1914 gas welding and arc welding with bare wire

electrodes were used for repairing castings and making small articles, but with the need for large quantities of war materials, made from thin steel plate, welding came to be increasingly used.

*Gas welding*

Gas welding came first. The temperature of the oxy-acetylene flame made it suitable for welding both ferrous and non-ferrous metals and its use spread over a wide field of application. While gas welding tended at first to be limited to the welding of thin steel and non-ferrous metals, its use for cutting came subsequently, and it is for this that oxygen, acetylene and other gases are now chiefly employed. With the improvement of equipment and technique, the thickness of material which can be cut by oxy-acetylene has increased to such an extent that there appears to be no practical limit to its application and the quality of the cut surface on all usual thicknesses compares favourably with that produced by mechanical means. Recent developments are the use of oxygen and fuel gas for de-seaming, de-scaling and gouging.

*Electric welding*

Gradually it was found that the greater heat of the electric arc made arc welding a better method than gas welding for dealing with thick steel plate, while resistance welding, particularly spot and seam welding, were used for welding thin material.

The original methods were developed in Sweden and in Russia about 1900. The method used was to melt a bare steel wire by the heat from a carbon arc or from an arc generated at the end of the steel wire itself as the electrode. The molten metal produced was then used for joining the abutting edges of steel to one another. The resulting weld lacked uniformity and ductility and these defects were traced to the presence of nitrogen (up to 0·14 per cent) in the weld metal. Steps were therefore taken to apply a suitable coating to the electrode to eliminate nitrogen. The development of the covered electrode from 1912 onwards has led to the production of weld metal comparable with the steel to be welded and has enabled arc welding to be applied to almost all engineering structures.

An outstanding pioneer effort was the building, in 1920, of the first all-welded ocean-going ship, s.s. *Fullagar*, but the effort was not followed up and it was not until 1931 that the next all-welded ship of any size was built in this country. Meanwhile, the inherent water-tightness of welded joints led to the use of welding for the manufacture of storage tanks and containers of all kinds, as well as large pipes and ducts where the simplicity of making branches and bends by welding had obvious advantages. From 1925–30, welding was used for petrol storage tanks, and since that time it has come to be used to an even greater extent

for all chemical and industrial plant, particularly where the conditions of service are severe.

The possibilities of welding for heavy construction were demonstrated by the building of 'stator' frames for large electrical machines, and by 1930 stators and rotors for the largest units, with plate thicknesses of 4–6 in., were being fabricated. The use of welding for buildings and bridges which was being developed on the continent during 1930–38 was represented in this country by a few notable examples.

*Electrical resistance welding*

Resistance welding was invented in 1886 but development was slow until 1900. Up to 1914 the spot welder was in use mainly for making simple domestic articles. The slow-butt welder which was developed at the same time found application in the welding of locomotive boiler tubes and other railway gear such as draw-bars. In 1922 the introduction of flash butt-welding, which lends itself readily to automatic control, met the needs of mass production methods in the automobile industry and the use of resistance welding made great strides. In 1934 with the introduction of the all-steel body, the motor-car body became an all-welded product. During this period, resistance welding came into use for making window frames, railway carriages and the attachment of tube flanges. The Registration Societies in 1932 extended the application of resistance welding to tubular work on ships. From 1932 increasingly large machines for welding were introduced because electrical supply difficulties were overcome by the introduction of the Grid, and machines up to 1200 KVA were installed. Improvement in the specialised automatic control equipment greatly assisted the extended use of the process and the spot-welding of aluminium alloys began about 1936. A wide range of special electrodes for welding high tensile and stainless steel has been introduced and also electrodes for dealing with light alloys in addition to those of aluminium.

*Research*

Apart from testing work, e.g. in connexion with the building of the s.s. *Fullagar*, the scientific examination of strengths and stresses in welded joints began in 1925–26. In that period Höhn in Switzerland and Dustin in Brussels made a study of these stresses and drew up methods of design to meet them. Testing work was further called for because the Registration Societies required evidence before accepting electrodes for use in shipbuilding and called for tests of welded structures that were to be incorporated in ships. From 1930 onwards in Germany, Switzerland and the United States, investigation of welded joints and girders under alternating stresses and static loading was made; while in 1936, statistics

of the strength of welds as made by some 60 firms were tabulated by the Steel Structures Research Committee of D.S.I.R.

*Co-operative research*

In 1935, a considerable advance was made when the Iron and Steel Institute, in collaboration with 17 other technical societies, organised a symposium on the welding of iron and steel. As a result an Institute of Welding was formed with a research council to frame and carry out a programme covering such a wide field as welding in ships, aircraft, pressure vessels and building structures. The work was conducted at a number of centres, partly in university laboratories but largely in the industrial laboratories of firms in the ferrous and non-ferrous industries. By 1939, valuable results had been obtained, e.g. on the weldability of high tensile alloy steels; on the welding of non-ferrous metals such as copper and aluminium and its alloys; on welded ship structures; on the load carrying capacity of rigid frameworks; on the welding of pressure pipe-lines; and on spot-welding of light alloys. This initial effort has been so successful that a Welding Research Association is being formed to carry on the work of the Institute of Welding which will continue to be closely associated with it. It may be found desirable to institute central laboratories to undertake some of the future investigations, but like the recently re-formed Iron and Steel Research Association, much of the work will continue to be done in close collaboration with firms in their laboratories. By the end of the first three years of the co-operative research under the Institute of Welding, the annual expenditure on research amounted to £5,000–£6,000 but the new Research Association contemplates an annual outlay of £25,000–£30,000.

*Growth of the industry*

The growth of the electric arc-welding industry has been rapid and continues, as the quantities of coated electrodes manufactured and sold for use in this country indicate. In 1932 about 7·8 million lb. weight were produced; in 1936, 18 million lb.; in 1940, 46 million; in 1942, 66 million and, in 1943, 97 million lb.

Another striking indication of the growth of the practice of welding is furnished by the consumption of electrodes compared with the quantities of ingot steel produced:

*Electrodes (lb.) produced per ton of ingot steel manufactured*

| | |
|---|---|
| *1932* | 1·25 lb. per ton |
| *1934* | 1·32 ” |
| *1936* | 1·68 ” |
| *1938* | 2·2 ” |
| *1940* | 3·35 ” |

# CHAPTER 14

# OIL

### *Sources of supply and general uses*

The use of petroleum for industrial purposes either as a source of power or of chemical products makes a short note upon it necessary. The world production of petroleum in 1886 was 3 million tons; in 1938, 268 million or rather more than the amount of coal mined in this country in the same year (227 million tons). Of the world production in 1940, 63 per cent was derived from the United States, 34 per cent from Central and South America, Russia, Iran and Iraq and rather less than 3 per cent from the British Empire.

The shale oil deposits in Scotland have been the sole source of supply in this country until very recently when prospecting has shown that oil deposits do exist elsewhere in the United Kingdom. In 1938, 1½ million tons of oil shale were raised, of which 80 per cent resulted in spent shale some of which is utilised for making bricks. The production of oil from coal by hydrogenation is dealt with elsewhere (p. 37) but it will be seen that this country is mainly dependent upon imported oil.

The first and for many years the only use made of kerosene distillate from petroleum was for lighting, later extended for jet aviation, agricultural motors and fishing vessels. Further distillation and 'cracking' of crude oil yields petrol of various grades for aviation and motor transport. The heavy oil is used for Diesel engines while waxes, candles, bitumens and lubricants are also major derivatives. In 1939, 30 million petrol-driven motor vehicles lubricated from petroleum sources transported passengers, their food and the raw material of their industries as well as livestock.

### *Refining*

When an oil formation is struck a mixture of oil and gas emerges and after separation of the gas the crude mineral oil has to be refined. The initial processes take place at or near the source of supply, usually on the sea board, and constitute but a minor industry as conducted in this country when compared with similar undertakings in foreign countries. On the other hand, in order to improve refining operations at oil concessions abroad, e.g. Iran and Iraq, research work is done in the United Kingdom to be put into practice at oil centres overseas.

The 'dry' gas, i.e. that liberated in gaseous form as distinct from 'wet' gas where it is in solution in the liquid oil, is chiefly composed of methane (over 80 per cent) with smaller quantities of ethane, propane, butane

and pentane. The wet gas on the other hand contains considerable quantities of the lower volatile hydrocarbons suitable for motor fuel. These volatile products are largely converted into liquids at the refineries either by compression or by solution in oil or in activated charcoal.

The refining process in the first place is a thorough fractional distillation yielding a whole series of products of increasing boiling temperatures ranging from motor spirit to lubricating oils and waxes and a bitumen residue. The gaseous hydrocarbons such as methane are converted into carbon black for printers' ink and as a filler for rubber tyres and other rubber goods. Furthermore, these gases, and those derived from the cracking process referred to below, are now an ever increasing source of supply for synthetic derivatives. After the main separation by distillation, a variety of chemical and physical methods are employed in the final treatment of the fractions to render them suitable for the market. Up to the beginning of World War I all petrol was straight-run from crude oil which yielded about 20 per cent of motor spirit. The increasing demand for aviation and transport purposes brought about investigation of ways to convert heavy oils into lighter fractions and the process of 'cracking' was devised. Cracking consists in the thermal decomposition of the heavier into less complicated hydrocarbon molecules and this country has contributed to our knowledge of it. Today, however, highly specialised synthetic methods are employed in the manufacture of aviation spirit.

While coal tar and cellulose provide about 85 per cent of the raw materials required for making plastics, the remaining 15 per cent is derived from other materials of which petroleum is an important source. Synthetic rubber is derived in the main from products obtainable from petroleum.

*Research*

America has naturally been the source from which progress in winning petroleum has come and it has made many advances in the refining processes, but research into the problems of petroleum is conducted extensively by the Anglo-Iranian Oil Company, which through Scottish Oils Limited operates the shale oil fields and refineries in Scotland. Oil technology is an important subject in centres of university research, especially at the Imperial College of Science and Technology and Birmingham University. But the absence of large indigenous sources of supply has naturally not led to the training of oil technicians to the extent that exists in the United States. The analogy of the cotton industry is not a true one, since the state of knowledge and the mechanical facilities that existed here at the time of the industrial revolution placed this country in a position far more favourable than that existing on the formation of the oil industry.

# CHAPTER 15

# PAINT

## *Historical*

The history of paint is a long one as the wall paintings in cave dwellings prove. In the early civilisations the craft was largely used in the ornamentation of all kinds of structures and objects. Some of the work, of special religious significance, was extremely rich both in design and execution, as witness the brilliant colouring on Egyptian mummy-cases.

In the Middle Ages, a great deal was known about the materials used, and the craftsmanship of the Old Masters in preparing paints for their pictures was not the least of their attainments. The instructions and recipes were jealously guarded secrets handed down in the schools of the accepted masters and sometimes from father to son. The media used were egg, milk, honey, glue, wax and various resins like mastick, sandarac and probably amber, pitches akin to bitumen and oil of cedar. Later, turpentine and other volatile oils were employed. Oil paint based on linseed oil was not known before the 14th century and was probably not appreciably used till the 16th century. White lead was known from fairly early times and the brilliant work of the Middle Ages depended mainly on cinnabar for vermilion and lapis lazuli for ultramarine blue with plenty of gold leaf; the other colours, reds, yellows and browns, consisted mainly of the natural earths, such as a variety of iron oxides and the yellow sulphide of arsenic.

The modern industry dates from the time when centres of paint manufacture were established for the supply and distribution of more or less prepared material to painters. It is difficult to say when such organised production of paint began, for the transition from picture painter to house painter was gradual. In the Middle Ages, the description 'painter' implied the artist who beautified the palaces, the religious buildings and the like with suitable subjects. Gradually the increase of wealth brought the artist's work into the homes of more and more people, and concurrently, the artist found that wall decorations in formalised patterns (as in woven carpets) were acceptable. By this means the painting and colouring of cloth which finds its modern expression in fabric wall coverings (often spoken of as artificial leather) and linoleum came to be developed. Both these modern industries are essentially 'paint' industries since they depend largely on linseed oil

and pigments, consuming as much of these materials as all the rest of the paint industry.

The word 'paint' implies a composition consisting of a solid material (the pigment) in a fluid material (the medium), prepared for application to a surface. Paint and varnish are closely related products. To the artist, painting is not complete without varnish. Varnish is an ingredient of many paints but paint is often thought of as the foundation and varnish as the finish.

The paint manufacturing industry has not had an existence for much more than 100 years. Varnish making, the treatment of natural resins to render them soluble in linseed oil, goes back a little further and was introduced from Holland in the late 18th century. The art has been a jealously guarded possession of families who have served specialist firms for generations.

*Growth of the industry*

From about 1850 England had been the premier varnish making country of the world and the industry enjoyed great prosperity, but at the turn of the century chemistry began to have its effect and the industry had to embark upon new materials and methods. Those who have guided the industry have recognised the need to preserve as much as possible of the age-long craft traditions and to link them with the new. Great strides have been made and by 1935, the annual production was valued at about 22 million sterling with an export trade of 3 million. While there are a number of specialist firms confining their attention to special products such as varnishes, marine paints and bituminous emulsion paints, the tendency has been, and is, for firms to widen their interests and undertake the manufacture of a range of coating compositions, to be used for such widely separated objects as the lacquering of pencils or the painting of battleships.

*Uses of paint*

Paint is used with two objects: to serve as decoration and to provide protection to the material on which it is placed; and there are combinations of the two aims. Distempers and oil paints for internal use in houses are examples of the first object, while external house painting is mainly for the latter purpose. The largest part of the retail trade of the industry is derived from these demands. An important use of paint is for factory buildings and for the protection of steel structures. The painting of the Forth Bridge goes on day-in and day-out without intermission. Paint is also important as a protection for industrial and chemical plant to prevent corrosion. The under-water parts of ocean-

going vessels are also protected by special paints against fouling, while resistance to the weather conditions aircraft have to encounter has caused rapid development of lacquers suitable for that purpose. The protective properties of paint are consequently of major importance.

*Development of pigments*

The progress of the industry as a result of research and development has taken place in all directions. First in regard to pigments: white lead was the original white pigment followed by zinc oxide. Lithopone (co-precipitated barium sulphate and zinc sulphide) was next introduced and by the 1920's its fastness to light was secured. Meanwhile, titanium dioxide was developed on account of its high tinting and hiding power, and antimony oxide is a still newer addition to the white pigments. At the beginning of the 20th century a wide range of coloured pigments was made directly from natural ores, notably the iron oxide ores, but more recently synthetic iron oxides of controllable quality have become available. Among materials produced by precipitation processes, are the famous colours Prussian blue and lead chrome and the equally well-known Brunswick green obtained by mixing them, all of which have been used for many years. Of late years, the palette of commercial pigments has been greatly extended by the manufacture of synthetic pigment dyestuffs, organic colours and lakes in great variety.

*Development of media*

Oils and media generally have been greatly improved, especially the preparation of linseed oil and its heat treatment. It was a notable discovery that by bubbling air through hot linseed oil, a quicker drying product was obtained. The paints so made were easier to handle and to apply and the films were more water resistant than those made with straight linseed oil. Linseed oil as a medium had no serious rival for general purposes until the beginning of the present century. A new rival at that date was tung oil, sometimes called China wood-oil. The exceptional properties of tung oil are its capacity for making quick-drying, highly durable and resistant coatings and its outstanding properties were recognised during World War I. Since that date, tung oil has held a unique place in paint and varnish technology and in the inter-war period great efforts were made to increase the supply of it in the Empire. Progress has been made. The greatest efforts are now being directed to transform linseed oil (and to a certain extent other drying oils) into products more nearly akin in their properties to tung oil. If successful, a very important advance will have been made.

*Synthetic resins*

In the early part of the present century, the resins used were natural in origin—various copals from the East Indies, East and West Africa and other places, kauri from New Zealand, shellac from India and much resin from pine trees from the U.S.A., France, etc. were employed. These resins are still extensively used but the impact on the industry of synthetic resins has been profound. The first phenol-formaldehyde resins were used in the form of solutions in volatile solvents such as alcohol and regarded as shellac substitutes but, in the 1920's, oil-soluble types were introduced. Then came urea-formaldehyde condensates and metal resinates for special uses and more recently, a large variety of other synthetic resins. The alkyd resins, oil-modified products of the primary reaction between glycerol and phthalic anhydride (a coal-tar product), have developed enormously. They are produced by the thousands of tons and yield quick and hard-drying coatings of high quality and durability. Uniformity in chemically produced synthetic resins, absence of impurity, reasonable cost and ease of working are all attractive reasons for their greater production and use.

*Cellulose lacquers*

Prior to World War I the familiar lacquer coatings on motor cars were almost unknown and the wide use of cellulose lacquers by the motor industry dates from about 1923. The war had brought into being extensive and well-equipped plants for the production of nitro-cotton for war purposes, especially in the United States and the need for a peace time use for them led to research work leading to new nitro-cellulose lacquers. The mass-production of cars in the U.S.A. was helped by this development of quick-drying cellulose enamels and lacquers capable of giving brilliance of finish and adequate covering protection in two or three coats in a matter of hours instead of days. In turn, the cellulose enamels and lacquers, though still greatly used, have been improved and altered considerably by the concurrent development of the synthetic resins. Together they rival the old industry in many fields. The development of synthetic resins has aligned the paint and varnish industry with the plastic industry. The vinyl, acrylate and styrene types of resin are suitable as paint media in various directions including chemical resistant finishes and insulating varnishes.

*Water base paints*

The aqueous paints which began as the crude dispersion of lime in water and of pigments in albumen or in casein, glue or gelatin (broadly described as distemper) and developed into emulsion-type paints, of

which oil-bound water paints are well-known examples, have been greatly improved by scientific investigation. The products when pigmented give coatings of much enhanced interior durability and lustre and methods have been found to use such materials for outdoor exposure. Considerable quantities of such emulsion paints have been used during the war for camouflage purposes. Other materials besides oil and varnish are also used in emulsion form, notably bitumen, and some of the new synthetic resins dispersed in water are being used in the same manner.

*Application of paint*

Apart from the new paints and varnishes, the introduction of spray painting has had an almost revolutionary effect on the even and rapid application of paint. The original idea of a paint gun was based on a medical atomiser or scent spray and was first used in the early part of this century. The modern form only came, however, when the difficulties of applying extremely rapid-drying materials became apparent. Spraying of paint instead of applying it with a brush has many obvious advantages and areas difficult of access by a brush can be reached by a spray. The paint gun is of high importance in mass production. The objects to be coated can be brought to the spraying department on conveyors, passed through a stoving and drying chamber and passed out in a continuous operation. Nevertheless there are disadvantages in this device and the paint brush, for many purposes, is not likely to be abandoned. Each tool has its proper place and function and in certain cases the best work is done by a combination of the two methods.

*Co-operative research*

There are few industries based on an ancient craft which have felt the impact of science more than the paint industry and the brief outline of developments sketched above bears out this fact. To meet modern conditions every section of the industry has had to apply new scientific knowledge to its materials, to its methods of production and to the application of its products in commercial practice. As a result the leading firms in the industry employ scientific personnel who plan research and development work, while many of the smaller firms have staffs to investigate troubles arising in the use of their products and these may lead to deeper-seated investigations.

For both classes of firm the Research Association of British Paint, Colour and Varnish Manufacturers has rendered notable service. By means of panels of experts from the industry, working through a technical advisory committee appointed by the governing body, the closest

touch is kept with industrial requirements, and a programme of research is drawn up. The plan is to pursue continuously long range problems of interest to the whole industry and to deal with more immediate problems peculiar to particular sections. Since its establishment in 1926, a great change has been brought about in the appreciation of the scientific needs of the industry and advances have been made in the methods and materials employed by contributing firms. The Association is, however, on far too slender a financial basis to provide a full scientific service. Its industrial income in 1939 was barely £10,000; but there are prospects of wider and increased financial support.

# CHAPTER 16

# PAPERMAKING

## *Historical*

The desire to record, with some degree of permanence, the incidents of life and the thoughts of man, has existed throughout the ages. In earliest times, he used materials which required, essentially, surfacing or surfacing and joining, e.g. stone, brick and wood, skin and leaves; but some of these were clumsy to store, difficult to write on and, for practically all purposes, they have been replaced by paper, a material which, in contrast to these others, is almost completely fabricated. Papyrus was made from the stem of a reed (Cyperus papyrus) by a process analogous to that used for paper, but worked as a dry and not a wet process. The invention of paper as a felted mat of interlacing fibres, was first reported to the throne in China by Ts'ai Lun in A.D. 105. There is little doubt that 'paper' made from silk filaments existed earlier, but Ts'ai Lun's name is linked with an invention which used less costly materials. His raw materials were bark, heads of hemp, rags and fish nets. If we exclude silk and include cotton and linen, similar raw materials were used in the West until the early 19th century and are still the basis of some of the best grades, e.g. ledger papers. The method of making this was a closely guarded secret which did not pass out of Chinese hands until the 8th century. Even then, the secret was disclosed only as a result of force. In A.D. 751, the Arabs were at war with China; amongst the captives they took were some Chinese papermakers and, with them, the Arabs established the first paper mill outside China in Samarkand or Bagdad. Thereafter, the story of the travel of paper from East to West is the story of the Arab Conquest. The Arabs not only adopted it as their sole medium for writing but in their turn exported it. In Egypt for instance, paper replaced papyrus and, by the 10th century, paper was universally employed in Eastern Europe and had partially replaced parchment in Western Europe. It was not, however, until the 13th century that paper mills were established in Italy and Spain, the countries most under Arab domination. Two centuries later, in 1490, the first mill was established at Hertford in England, by John Tate.

## *Manufacturing processes*

The fundamental processes of papermaking remained unchanged until the 18th century, and even today the underlying principles are still the

same. The raw material (rags) was reduced to the ultimate fibres by retting them for 30 days or more, in piles that were continually damped, the excess water being drained off through porous bottom-plates or tiles. When sufficiently softened, the rags were disintegrated with water in a pestle and mortar so that, first, the fibres floated separately: and they were then reduced in length, bruised and rendered flexible. At a later date stampers, run from a water wheel, were introduced to carry out the same operation. The fibres were next suspended in a large quantity of water so that they floated freely and uniformly, and into this was plunged a flat sieve or wire mesh. As the sieve was drawn up through the water, the water drained through and the fibres, pointing in all directions, were deposited on the wire and there remained as a felted mat which could be transferred to a flat surface to be dried and pressed. Smooth finish was obtained by polishing with glass, polished wood or stone, and sizing by immersing the sheet in vegetable gum and, latterly, in animal gelatine.

In 1717 the hollander, or beater, was introduced; it replaced the stampers. The hollander consisted of a vat which could be filled with rags and water: in it rested a roll, or cylinder, along the outside of which were fixed metal bars or knives, lying parallel to the axis. This roll was rotated at high speed over a set of stationary bars set firmly in the bottom of the vat and also lying parallel to the axis of the cylinder. As the roll rotated, it dragged water and rag, or water and fibre between the moving and the stationary bars and thus a mass of individual, bruised fibres was obtained in a much shorter time. This beater has since been increased in size and improved in design and efficiency, but it remains in principle the same today.

The preparation of the fibre having been speeded up, the next change came in the formation of the sheet. Preparation by hand of individual sheets was laborious but finally means were evolved for forming a continuous web of paper. The method was worked out by Robert in France, and perfected by Fourdrinier and Bryan Donkin, who set up a mill of this type at Frogmore in 1800. A continuous travelling wire cloth, on to one part of which the aqueous suspension of fibre was delivered and from another part of which it could be removed as a wet web, replaced the hand mould or sieve. Presses to remove water continuously and steam-heated drying cylinders round which the wet web could be passed completed the Fourdrinier machine. This is the type of machine on which nearly all paper is now made.

The Fourdrinier machine in its modern form is capable of turning out some tons of paper an hour, the beater has increased in size and efficiency to correspond, and the paper finally produced is so varied in characteristics and quality, that while one sheet is a printing base to

the printer, a second is an insulator to the electrical industry, a third a mould and reinforcing agent to the plastic industry, and a fourth the foundation of vulcanised fibre. Further, in addition to its use as an ordinary wrapper, paper is playing, and will continue to play, an increasing part in the delivery of foodstuffs in a hygienic condition.

### *Other raw materials*

Developments in other industries in the late 18th century and early 19th century enabled the preparation of the raw materials to keep pace with the ever increasing production of paper by the Fourdrinier machine. Caustic soda reduced the process of retting from days to a few hours, and chemical bleaching replaced sun bleaching. Rosin, which can be added to the beater to make the finished sheet resistant to ink, eliminated the earlier process of sizing with gelatine. The demand for the printed word, due to the spread of education, called for more and still more paper and the scale of production outgrew the available supplies of raw material. Hence, in the 19th century, two further sources of fibre, esparto and wood pulp, were called into use, both being dependent on the advance in chemistry already mentioned. Esparto grass was introduced in 1856. The Journal of the Society of Arts, November 28th, 1856, was printed on paper exclusively made from esparto grass at the mills of Thomas Routledge, Eynsham, near Oxford. Wood pulp was introduced in 1860.

The manufacture of esparto papers is almost wholly a British industry. Esparto grass, in its natural state, is imported from North Africa and Spain; after cleaning, it is boiled with caustic soda so that only the fibres remain undissolved. The fibre, or pulp, is then washed and bleached and, after treatment of the kind described above, it is converted into what are known in the trade as esparto papers, which give excellent printing results.

### *Wood pulp*

The mainstay of the paper industry and of various other cellulose industries, however, has been wood. Since wood in this country is not available in sufficient quantities, little is done to produce pulp from home grown timber and a large amount of wood pulp is imported, chiefly from Scandinavia and Finland and also, though to a less extent, from Canada and the U.S.A. But these two countries, during World War II, increased their production to meet the demand due to the failure of the supply from Northern Europe.

In all these countries, considerable study has been given to improving and varying the qualities of their pulps. Broadly speaking, there are

three methods of preparation: (1) the sulphate, an alkaline process and a variation of the soda process; (2) the sulphite, an acid process, and (3) the mechanical process, which grinds the wood or log without previous chemical treatment. The first produces, essentially, low-coloured but strong pulps for wrapping and technical papers; the second, lighter, bleachable pulps for writings, printings and other white papers; the third a weak, bulky, light grey pulp for newsprint and box-boards. In recent years, there have been considerable advances in the refinement of all these grades so that the generalisation given above is only approximate; the selection of the right pulps to give the required characteristics in the finished paper is becoming an important factor in papermaking.

*Organisation of the industry*

The industry has, since 1912, been organised as a unit under the Paper Makers' Association of Great Britain and Ireland. This body was the result of the amalgamation of The Paper Makers' Association of Great Britain and Ireland (1872) and The Scottish Paper Makers' Association (1860). It has sought the advance of the industry generally, has endeavoured to maintain it in a healthy condition, and has throughout been conscious of the fact that efficiency could only be maintained by endeavouring to understand and improve its methods. In 1920 it formed the Technical Section of the Paper Makers' Association, an organisation which, by free discussion of the investigations of the constituent firms, has helped to elucidate some of the processes involved in papermaking.

*Co-operative research*

The Paper Makers' Association is engaged in forming its own Research Association so that, by means of concentrated and co-operative effort, the efficiency of the industry may be further increased. The industry has indicated its willingness to contribute a minimum of £15,000 per annum to the funds of the Research Association.

*Size of industry*

The industry is not a small one. The Census of Production for 1924 returned the total value of paper sold or added to stock (not including cardboard, millboard, etc.), as just over 21¼ million sterling: in 1930 the figure was approximately 33 million. Of these totals, about 18–20 million represented printing paper and consisted about equally of newspaper and of other printing paper. The estimated home production in 1938 under the main headings of manufacture was as follows:

| | Tons |
|---|---|
| Newsprint - - - - - - - - - | 796,816 |
| Other printings - - - - - - - - | 487,514 |
| Writings - - - - - - - - - | 151,174 |
| Packing and wrapping papers - - - - - | 365,558 |
| Cigarette, blotting, vegetable parchment and other uncoated papers - - - - - - - | 118,170 |
| Coated papers and coated boards - - - - - | 115,695 |
| Boards - - - - - - - - - | 466,303 |
| Total | 2,501,230 |

The total imports of paper, cardboard, etc. for 1938 amounted to 1,070,696 tons estimated in value at £14,841,996. In the same year the total imports of paper-making material amounted to over 2¼ million tons, of the value of about £16,000,000.

# CHAPTER 17

# PHOTOGRAPHY

## *General uses of photographic science*

The use made of photography in other industries is touched upon elsewhere; e.g. the printing industry (p. 139). It is also of great importance in the medical profession, especially in radiography. It plays an essential part in motion picture production and has been of first importance for military operations. Photography is used in many industries for facilitating their production methods. Not only so but as a research tool in control and recording apparatus it is a highly important means of recording experiments. In addition much of the scientific knowledge arising from the evolution of photographic chemistry is applied in connexion with molecular distillation, the manufacture of vitamins, fine chemicals, plastics, paper, gelatine and cellulose films.

## *Historical*

One of the earliest published accounts of any attempt to produce images by the decomposing power of light on silver salts was Tom Wedgwood's paper in 1802 in the Journal of the Royal Institution which was accompanied by observations from Sir Humphry Davy. Daguerre in 1839 announced the result of the experiments, made with the important help of J. N. Nièpce, which led to the process that bears his name. The basic principle of negative production as an intermediate stage in the making of positive prints by means of a sensitive silver emulsion was enunciated by Fox Talbot (also in 1839). His work was supplemented by that of another amateur scientist, the Rev. J. B. Reade, and also by Sir John Herschel who evolved the use of 'hypo' for 'fixing' the developed image by dissolving the unexposed silver salts of the silver halide emulsion. It was Herschel who first adapted the method to make transparent negatives on glass plates. These early men of science furnished the groundwork of the highly perfected technique of today.

The achievement of Fox Talbot was of far-reaching significance in leading to his discovery of the hardening action of light on a bichromated colloid upon which almost all photo-mechanical reproduction processes have been based. That discovery coupled with Scott Archer's invention (1850) of the wet-collodion process was of the first importance, and led to the production of collodion covered dry plates in 1854 when Gaudin, Muirhead and Taupenot made that advance. Another early landmark was the invention of the gelatino-bromide emulsion as



Plate III. Guests at banquet given by Sir Kenneth Lee in 1934 photographed by infra red radiation in apparently complete darkness.

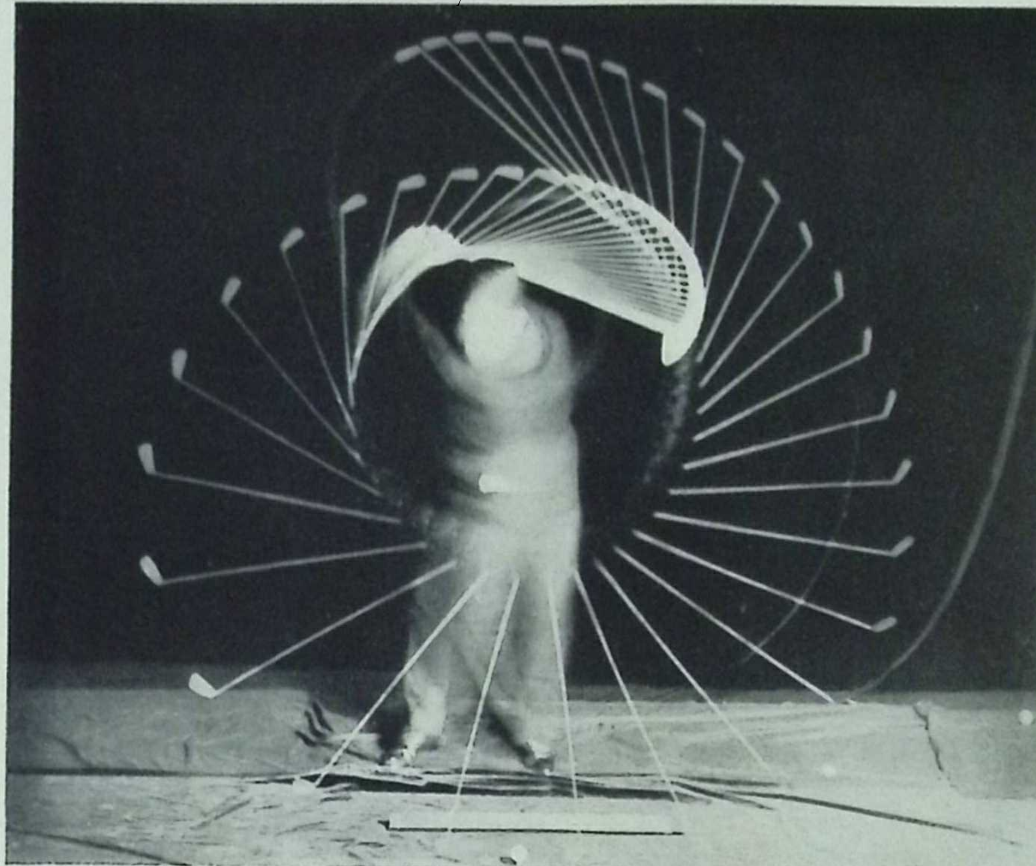


Plate IV. Multiple-flash photograph of Bobby Jones making an iron shot. Time interval between photographs is $\frac{1}{100}$ of a second; and time of exposure of each photograph is $\frac{1}{100,000}$ of a second.

a working basis for sensitive materials for negative making and print production. This was due to Dr. Maddox in 1871 and led to commercial development here and elsewhere.

In the pioneer scientific work in this country Hunt, Abney and Waterhouse achieved early prominence, while the classic researches of F. Hurter and V. C. Driffield in 1890 and subsequent years added greatly to the scientific study of photographic phenomena. The system of photographic speed measurement devised by the last two has been outmoded, but their exploration of the quantitative relationships of the photographic process placed it for the first time on a sound basis.

In 1889 George Eastman discovered a practical way of coating a nitrocellulose film with an emulsion. His introduction of flexible sensitised film, in roll form, made possible the cinematograph and the modern roll-film hand camera. Amateur photographers previously numbered by the hundred were soon to be counted by the thousand, and 'Kodak', the original trade name of Eastman's hand camera, became a household word.

The early stages of cinematography also date before the 20th century. In 1889 the Friese-Greene patent was taken out, and this supplemented by the patents of Le Prince, a Frenchman long resident in England, of R. W. Paul and of A. S. Newman, together cover all the essentials of the making and projection of motion pictures. The development of cinematography proceeded simultaneously in France (Lumière), the United States (Edison and Jenkins) and Germany (Messter).

*Developments in the 20th century*

Organised research in contradistinction to that of individuals was first undertaken in this country by the firm of Wratten and Wainwright, and the work there conducted by C. E. K. Mees and S. E. Sheppard was of such importance that the firm was absorbed by Messrs. Kodak, and Dr. Mees was transferred in 1913 to become the head of the research laboratories in the Eastman Kodak factory in the United States—the largest organisation of its kind in the world, employing in 1939 a total staff of 38,000 of which about 500 were engaged solely on research.

The 'speed' of plates and films was much advanced by the discovery of Sheppard in the Eastman Kodak laboratories that mustard oil derivatives increase materially the sensitivity of a photographic emulsion by the formation of silver sulphide specks on the surface of the silver halide crystal to nucleate the photolytically released silver atom. The use of this discovery has greatly increased the speed of plates and films in the last 20 years. These and other results of research have brought us much nearer the long sought aim of combining great speed

with fine grain. During the war it has been possible to produce for military purposes films of previously unthought-of speeds.

*Co-operative research*

The photographic industry is a good example of the 'give and take' relations which research stimulates not only within a nation but between different countries. The British Photographic Research Association was one of the first Research Associations to be formed and during its existence, apart from bringing firms together, did valuable work in connexion with the basic mechanism of the reactions upon which the photographic sensitivity of silver halide crystals depends, the influence of the environment of the crystals in a photographic emulsion, and the methods of measuring the sensitivity of photographic materials. Since the Association ceased to function, due mainly to an important amalgamation of British photographic firms, research has been concentrated in the laboratories of the great firms, notably Kodak Ltd., and Ilford Ltd., where not only are manufacturing problems dealt with but those of a long range nature.

The long range researches carried out in University laboratories as well as in the Ilford, Kodak, and Eastman Kodak laboratories on the mechanism of the formation of the latent image and on dye sensitisation have led to much improvement in sensitive materials. As a result emulsions of greatly increased speed and colour sensitivity have been produced. The first panchromatic plates using sensitising dyes had been marketed by Wratten and Wainwright in 1906, and in 1908 this type of plate was adopted by photo-engravers for making three colour half-tone separations for coloured illustrations. The same year saw the successful introduction of screen-mosaic colour plates giving transparencies in full colour by reversal development.

Subsequent advances led by the time World War II broke out to the production in colour of transparencies on film which had already become a feature of cinematography for amateurs and for Technicolor films in the theatre. 'Kodachrome' transparencies for making miniature colour pictures by the amateur were becoming common at that date. The method, patented first by Fischer in Germany in 1912 but actually realised as a practicable proposition only in 1935 in the Eastman Kodak and (later) in the Agfa laboratories, depends on a colour 'coupler' development. A dye deposit accompanies the normal development of the black silver image so that removal of the silver leaves the image in colour. The same method is used for producing paper prints of colour pictures; it had been introduced in America by 1939 and would have been available here but for the war.

The discovery of a sufficiently non-flammable film on the basis of

cellulose acetate and the perfecting of a method of reversal development which would allow the same film to be used both in camera and projector, together with the introduction of film emulsion of fine enough quality to permit the use of minute images on films of only 16 m.m. or even 8 m.m. width, have brought the cinematograph into the home.

The development process has been considerably improved especially in recent years. The earliest processes were based on acid reactions, and the introduction of alkaline development by Russell was a notable advance. But early in the present century a time-and-temperature control of development was devised by Ferguson and Watkins and has become the basis of all modern tank-development processes. The ability to produce negatives in bulk and of uniform quality without periodic inspection of the image was of the greatest advantage, especially with the advent of highly colour-sensitive emulsions for which no darkroom light was safe.

Large quantities of silver are used in the industry. A considerable part of the silver which is applied to the film in the form of halide is removed in the fixing bath and in early days passed down the drain. The silver recovery processes devised by Hickman, an Englishman working in the Eastman Kodak laboratories, have greatly reduced the cost of using cinema film.

Another important advance in the same field was the introduction of developer replenishment systems. As the developer is used, changes occur in its chemical composition by the removal of some of the original constituents, which with the accumulation of development products reduce its action. By the addition of 'replenisher' solutions the effective life of the developer is lengthened and a reduction in cost secured.

*Latest applications*

The general services to which photography is put have been touched upon and it is only possible to indicate a few of the latest applications. Photographic copying is an instance. The 'Photostat' camera is much used for the reproduction of documents of historical or commercial importance. Another copying technique is micro filming, which is best known in its application to the 'Airgraph' and 'V-mail' services by which copies of letters are rapidly transmitted over great distances. High speed methods of photography and cinematography have given science and technology a new tool for the solution of problems involving high speed mechanisms, while in engineering the reproduction of templates by the application of photography has produced a great increase of speed of output, especially in aircraft production. Aerial photography apart from military requirements is of much value for mapping and surveying. The use of infra-red radiation not only allows for the taking of photographs

in apparent darkness but provides a means of long distance photography with greatly increased definition and haze penetration.

Photography is proving of great service as a further tool for the scientist. Fluorography (miniature photography of the X-ray screen image) has been developed in very recent years and so has X-ray crystallography. The former provides a new instrument for the combating of disease and the latter for studying the structure of materials, e.g. metals and alloys, fibres, etc.

*Cameras and lenses*

Space does not permit of more than a cursory reference to the considerable advances made in photographic apparatus. Optical lenses are also touched upon elsewhere (p. 162).

In the evolution of equipment for photography British craftsmanship made its own contribution. In the first fifty years of photography, when camera-making came within the province of the cabinet-maker, the studio and field instruments by such makers as Hare, Meagher and others, established a high reputation for quality of construction. British manufacture has developed along special lines. The reflex camera, for example, has been mainly the product of British invention—with Newman & Guardia, Adams, Watson and Soho models as examples. In the production of extremely versatile hand-or-stand instruments, of the type particularly adapted for record photography, the 'Sanderson' camera and the Sinclair 'Una' have had a fifty years' reputation.

Towards the end of the 19th century, amateur photography became a popular hobby, largely owing to the initiative of the firm of Lancaster of Birmingham in producing a wide range of light, collapsible field cameras of the plate type, with the quarter-plate ($4\frac{1}{4} \times 3\frac{1}{4}$ in.) as the most popular size. The vogue of the amateur field camera was eclipsed at the turn of the century by the roll-film type of camera introduced by the Kodak Company, but ten years earlier the initiative of such firms as Lancaster and Thornton-Pickard in making cheap, light quarter-plate cameras had already made photography popular. When the roll-film pocket camera arrived, to make snapshot photography the hobby of the multitude, British camera makers adopted the new design and developed it on distinctive lines. By incorporating large rising and cross-front movements linked to viewfinders which showed the user the exact effect of the lens displacement, pocket roll-film hand-cameras had much of the versatility of the older hand-or-stand camera. It is noteworthy that whereas the advent of colour photography is only now beginning to create a general demand for camera shutters with accurate exposure speeds, this characteristic has long been the exclusive virtue of the best types of shutter of British

construction. Moreover the only high-speed between-lens shutter with exposures shorter than $\frac{1}{800}$th of a second was produced by Messrs. Ross Ltd. before World War I.

In view of the vogue of the miniature camera which has grown up within the past fifteen years or so, it should be noted that a true miniature camera of British design had proved its practical efficiency nearly sixty years before the 'Leica' camera was marketed. In 1865 the astronomer C. Piazzi Smyth constructed a miniature camera for archaeological record work in Egypt. This camera, which had a 2 inch *f*/2 lens, was used to make negatives 1 inch square, on wet collodion plates, and the required records were printed from these diminutive negatives by enlargement. The detail of the image on these wet-plate negatives was so minute that the final prints, enlarged to 25 diameters, outclass the remarkable achievements even of the modern miniature camera. In more modern days the miniature camera such as the Newman-Guardia 'Baby Sibyl' is one of precision quality taking vest-pocket ($1\frac{3}{4} \times 2\frac{3}{8}$ in.) plates.

In the design of camera lenses Ross and Dallmeyer have been in the vanguard throughout the history of photography. To a British designer belongs the credit for one of the most outstanding and fruitful developments in lens computation—the famous triplet construction of H. Dennis Taylor, which forms the basis of the Taylor-Hobson-Cooke series of lenses. During the past thirty years English lens makers—Ross, Taylor Taylor & Hobson and Dallmeyer—have led the world in the design of anastigmat lenses of extreme aperture and telephoto anastigmat lenses of the non-variable type. Before the outbreak of World War II British-made lenses held a position of predominance even in the motion-picture studios of Hollywood—the most critical and exacting market in the world. Despite the legend of the superiority of German photographic lenses, British makers lead in photographic lens design.

# CHAPTER 18

# PLASTICS

### *Early years*

Although nitrocellular compositions ('celluloid') were developed and produced about the middle of the last century, and casein and 'bitumastics' were known towards its end, the birth of the modern plastics industry may be said to date from 1908 when Baekeland made a thermo-setting synthetic resin which was given the name of 'Bakelite.' But it was not until about 1930 that this new industry can be said to have come into prominence, at all events in this country. The formation of the Institute of the Plastics Industry in 1931, the Plastics Group of the Society of Chemical Industry in 1932 and the British Plastics Federation in 1933, indicate the interest which arose in the industry immediately after 1930. During the decade that followed, no other industry made such spectacular advances.

### *Main types of plastics*

Plastics may be broadly grouped into two main classes: those which harden on being heated (thermo-setting) and those which soften on heating (thermo-plastic). Apart from celluloid, casein and bitumastics, the first class was the only one developed in the early days and 'Bakelite' is the typical example. The greatest advances recently have been in the second group, though many varieties of thermo-setting products have been made from different chemical reactions. This country has been handicapped in the thermo-plastic field by lack of raw materials, especially of acetylene from carbide for the production of vinyl resins and synthetic rubbers and allied products. Until the loss of natural rubber supplies during World War II, the urge for the production of synthetic rubbers and therefore of acetylene was not great here, while Germany and the United States, with ample supplies of acetylene but with a shortage of natural rubber, were the leaders in the field. On the other hand, this country was prominent in other sections of thermo-plastic development during the inter-war period and the production of acrylic resins, of which 'Perspex' is the best example, stands to our credit. More recently polyethylene ('Alkathene') is another outstanding British achievement.

### *Fabrication*

These and other branches of the thermo-plastic group will be referred to later, but it is necessary first to give a short description of the progress

made in methods of fabricating both types. The original technique of moulding thermo-setting plastics from powder under great pressure and heat has been modified. New techniques have been adopted more rapidly elsewhere than in this country, but injection moulding (by extrusion) of thermo-plastics and ordinary moulding of thermo-setting materials have now become common practices here. Considerable advances have also been made in the shaping of transparent thermoplastic sheet, the extrusion of both thermo-plastics and thermo-setting products, the moulding of organic glass lenses and the production of thin films by extrusion, calendering and casting. Low pressure moulding (from atmospheric pressure to 100-lb. per sq. in.) has recently been developed, though principally in the U.S.A., as also has 'jet' moulding.

An important advance in fabrication is the high-frequency technique which depends on the principle that when an insulating material is subjected to a high-frequency field, heat is generated throughout the body of the material as a result of dielectric loss. High-frequency fields may be used for pre-heating moulding powders, laminating, sealing thermoplastic materials and the like. Another fabrication technique consists in the use of glass fibre and glass fabrics as reinforcing elements in laminated plastics.

### *Recent scientific advances*

The scientific advances since 1930 have been considerable. Much chemical work has been done on phenolic resins. These comprise a large proportion of the thermo-setting class in which phenol (carbolic acid) is chemically combined with formaldehyde; there are also the urea-formaldehyde and the casein-formaldehyde groups. The main methods of formation and structure of these products have been examined and this country has played a notable part in this fundamental work. Important physico-chemical work has also been carried out at Cambridge University, especially on the kinetics of polymer* formation.

Space does not permit a description of all the new varieties of plastics that have been evolved; still less, except in the most general terms, their mode of formation. But some of the outstanding products must be mentioned to show the wide range of materials that have become available—many of them the result of distinguished research and development work in the industrial laboratories of this country.

The acrylic resin, called 'Perspex' in sheet form, and 'Diakon' as moulding powder, is well-known as the substance from which the

* When two or more molecules of the same constitution ('monomers') combine they form a 'polymer', the properties of which are generally very different from the original monomer. Thus benzene $C_6H_6$ ($3 \times C_2H_2$) is a polymer of acetylene, $C_2H_2$.

windows of aeroplanes are made. It was first produced by Imperial Chemical Industries in 1931 and is made by polymerising monomeric methyl methacrylate. This glass-like substance has many of the optical properties of certain glasses with a tensile strength, weight for weight, of cast iron. It can be machined with ease. A somewhat similar plastic was evolved at the Chemical Research Laboratory at Teddington by condensing methyl-ethyl ketone with formaldehyde but the investigation has not gone beyond the laboratory stage. A still more recent, and as yet little explored, section of the same field has been investigated in the U.S.A. by the production of resins based on allyl alcohol. From these transparent castings can be produced which have a higher temperature resistance and, even more important, a higher abrasion resistance than either of the two resins mentioned above. They appear also to be useful as bonding agents in low pressure laminating and mouldings.

An important series of resins has been evolved at the Chemical Research Laboratory which possess base and acid exchange properties. They are derived from certain phenols and amines in combination with formaldehyde and are used for softening water and removing dissolved salts. The patents are held by the British Government, but it appears that manufacture under licence has proceeded more extensively in Germany and the United States than in this country.

The polyester amide resins are among the outstanding achievements of the U.S.A. The best known example is 'Nylon', a cold-drawing material with a greater tensile strength than natural silk. From it can be made a wide range of silk-like fabrics, rope strong enough to tow a glider across the Atlantic and bristles for brushes that have a life many times that of the animal product. The latest developments include the production of tapered monofils for bristles and methods of injection-moulding of the material. It appears likely that by ringing changes on the polyester condensations, new varieties will be produced with further repercussions on the textile industries and on bristle manufacture.

Polyethylene, marketed under the trade name of 'Alkathene' is a British achievement and the result of research by Imperial Chemical Industries. Its production is based on catalytic polymerisation of ethylene at very high pressures, and the resin is of high importance owing to its small dielectric loss under high radio frequencies, flexibility (even at low temperatures) and excellent resistance to chemicals and water. The melting point is about 115° C. Its main application is as a flexible high frequency insulator.

The vinyl resins are another important section of the thermo-plastic group and have been chiefly developed in the U.S.A. and Germany owing to the absence of adequate supplies of acetylene in this country, despite our wealth in coal. There are several varieties. Polystyrene,



Plate V. Modern aeroplane cabin with *perspex* windows.

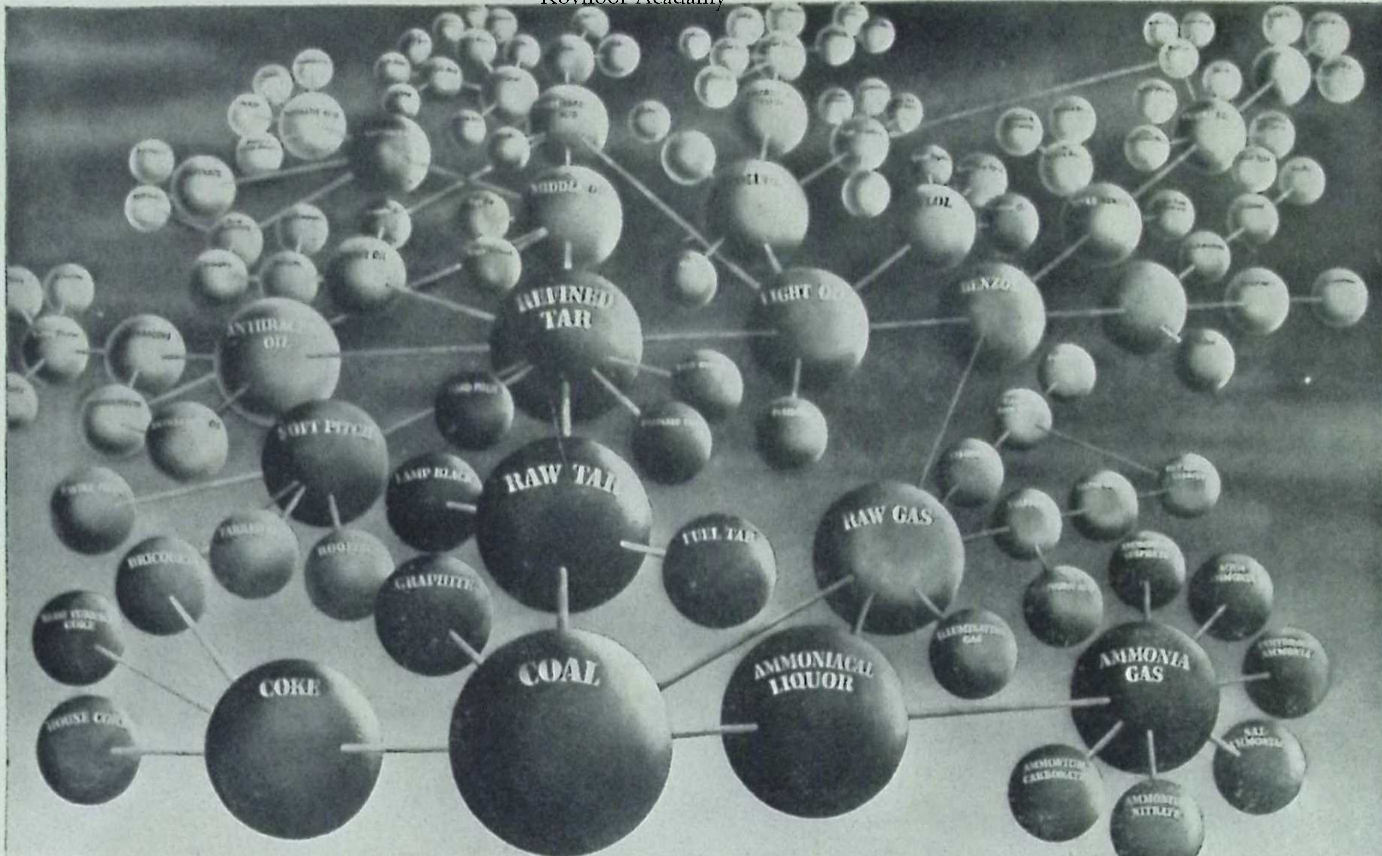



Plate VI. Diagram of products derived from coal.

marketed as 'Trolitul' in Germany, 'Victron' in the U.S.A., and 'Distrene' in this country, is prepared by polymerising monomeric styrene, produced by dehydrogenating ethyl benzene. The resin is of high value as a low-loss insulator and it has excellent chemical resistance with low water absorption. Another is polyvinyl chloride, based on the interaction of acetylene and hydrochloric acid. The resulting vinyl chloride is then polymerised under pressure or in emulsion with a catalyst. With plasticisers, compositions with a wide range of stiffness can be produced of great use as a substitute for rubber in cable sheathing. Allied varieties include polyvinyl acetate, polyvinyl chloride acetate and polyvinyl acetals, which are soluble in a wide range of solvents. They are much used as waterproofing agents, as adhesives and as safety-glass interlayers. Polyvinyl alcohol is of interest as it is insoluble in nearly all solvents except water.

*Synthetic rubber*

Reference is made elsewhere (p. 156) to synthetic rubbers, another important section commonly included in the plastics industry. The butadiene-styrene co-polymers have become the most widely used substitute for natural rubber although the technical difficulties in processing them have still to be completely surmounted. They are often used in combination with natural rubber because of their lack of tackiness. Butadiene-acrylonitrile is a variant with still higher resistance to oil and organic solvents but it is more brittle at low temperatures. The chloroprene polymers, of which 'Neoprene' is typical, provide a means of producing articles hitherto made from natural rubber, where oil and heat resistance are required. The greatest oil resistance of any synthetic rubber is provided by 'Thiokol' made from sodium polysulphide and ethylene dichloride; on the other hand, its tensile strength is low and even after vulcanization the material is comparatively thermo-plastic.

While, therefore, the synthetic rubbers evolved to date provide many of the essential characteristics of the natural substance and in oil resistance show superior qualities, a completely satisfactory substitute cannot be said to have been found as yet. The question of production costs is of high economic importance. Prior to World War II, the cost of 'Buna' was several times greater than that of natural rubber, but increased scale of production and improved methods are likely to reduce the difference.

*Other uses*

Cellulosic materials include nitro-cellulose, of which celluloid is the well-known example and cellulose acetate (see rayon p. 176) which dates from the beginning of the century. Variants on this basis have been explored by mixed esterification of cellulose, particularly by the formation of acetate-butyrate and acetate-propionate. The interaction of ethyl

chloride with cellulose produces a type of semi-synthetic plastics. Use is made of the products in cases where ease of fabrication, e.g. injection moulding, is important and in such applications as safety glass interlayers.

The alkyd resins, of importance to the paint industry, have been dealt with elsewhere (p. 112). Originally produced from glycerol and phthalic anhydride, variants can be made from many other polyhydric alcohols and polybasic acids. Their main use is in coating finishes where they can be modified with natural resins and drying oils. Their adhesion to metals is very good and the lacquers produced find important applications in high temperature resistant coatings such as those required for gas fires and stoves.

An important activity of the industry is directed to the development of resin adhesives and glues. Solutions of the different resins are used as bonding agents between the mating surfaces of the same resin composition and owe their adhesive effect to the partial solution of the mating surfaces by the solvent in the cement. For example two pieces of 'Perspex' can be bonded by a solution of that resin in toluene or chloroform so that the join is invisible, despite the transparency of the material.

The use of these adhesives is not, however, limited to this kind of application. Strong bonds can be obtained under good conditions between surfaces where no solution has taken place: thus a polyvinyl resin ('Formvar') is used in the production of laminated airscrews, and melamine (from dicyandiamide)-formaldehyde resins are of importance as hardeners of urea aircraft glues. The resin adhesives find their greatest application in connexion with laminated woods. The animal and casein glues have been known and used for a long time, but are becoming largely replaced by these synthetic resin-adhesives with their superior performance and resistance to moisture, bacteria and fungoid attack.

The production of impregnated and laminated woods is closely related to these adhesive resins. Laminated woods made from veneers bonded with protein glues have been largely superseded by the new technique and plywoods now made comprise resin bonded wood veneers; resin impregnated and bonded wood veneers; three dimensionally compressed resin bonded wood veneers; and impregnated paper.

This cursory survey of some of the main advances made during the last 10 years or so is sufficient to show what a range of articles can be constructed from materials unheard of 20 years ago; from motor-car bodies to cups and saucers, from gear wheels to optical lenses, from water-proof materials of all kinds to sponges, from brushes to stockings and from airscrews to fountain pens. In fact, it is difficult to name any article which is beyond the capacity of the research and development departments of plastic firms. The industry is only in its infancy, but already by 1935 the annual turnover was about 7½ million sterling.

# CHAPTER 19

# POTTERY

### *Historical*

Though pottery making was practised in this country in Celtic and Roman times, the industry may be said to date from the 18th century and is therefore of much less antiquity than that of China or the Near East. The Chinese industry is more than ten times as old and had begun its decline in artistic eminence when the British industry started. Josiah Wedgwood is regarded as the founder of the industry in this country, as we know it today, and the fact was signalised by the bi-centenary celebrations in 1930 at Stoke-on-Trent.

Traditions permeate the industry, and the craft on which it is based has given employment to generations of workers in the Potteries. Though there have been modern developments in certain directions, the traditional practices have not been greatly changed in their essential features and on the artistic side the high standards of the early days have been but rarely excelled.

### *Size and nature of the Industry*

In 1840 the value of exports in china, earthenware, and stoneware was £573,000, in 1850 £999,000, in 1860 £1,451,000, in 1870 £1,746,000, in 1880 £2,066,000, in 1890 £2,251,000, in 1911 £3,030,000, in 1935 £2,849,000 and in 1939 £3,300,000. Net imports rose from £165,000 in 1870 to £858,000 in 1911, but fell to £735,000 in 1935 and to £297,000 in 1939. The large drop in imports in 1939 was mainly due to the greatly reduced import of tiles from abroad, owing to the tariff imposed in 1936.

Technically the advances made have been in quantity production, especially in accurately dimensioned articles of complicated shapes. The products of the industry may be grouped according to the materials used into (*a*) fine china with a hard translucent body made from kaolin or china clay, Cornish stone and bone ash, usually with a lead glaze and with or without over-glaze enamel decoration, (*b*) earthenware with a non-translucent and porous body with a transparent lead or a leadless glaze, (*c*) stoneware with a denser but coloured body with or without glaze, (*d*) red pottery ware with a porous body covered with a transparent lead glaze, (*e*) fire-clay ware with a buff body and enamelled with a non-transparent tin oxide glaze.

From a trade point of view the industry is divided into the following sections: (1) china, (2) earthenware, (3) tile, (4) sanitary earthenware,

(5) fireclay, (6) electrical fittings, (7) jet and Rockingham (the section manufacturing teapots sold as separate units and not as parts of tea sets). All these sections have common problems but their incidence varies and they call for separate technical investigation. This fact was an added difficulty in the formation of a co-operative Research Association which was late in establishment compared with most of those set up by other industries. But perhaps the chief difficulty was the conservative outlook of the manufacturers. The frost of tradition yields here less readily than in most other industries and the process of thawing proceeds but slowly. The introduction of the steam engine in the 18th century led to the mechanisation of what was a rural craft but the effect was to increase output rather than to modify the essentials of existing practice. The bottle-shaped oven structure and the main processes employed have altered but little since the days of Josiah Wedgwood.

*Preparation of the body and mechanisation*

The material used for the body of the finer wares is white china clay which is most refractory, withstanding the greatest heat of the porcelain kiln. Ballclay is found in Dorset and Devon and has high plasticity and toughness, though lacking the whiteness of china clay in the unfired state. With these clays is mixed Cornish stone, containing felspar, mica and quartz, which on firing renders the body dense and vitreous. Additional silica is added, usually in the form of calcined flint, to increase the whiteness and give 'solidity' to the body.

The refinement of the body ingredients, especially those for the finer wares, is effected by the reduction of clay to 'slip', as the clay suspended in water is termed. The suspension is stirred by mechanical means in a gate 'blunger'. The mixing was previously done by hand. The knife-blunger, devised by W. Boulton about 1870, completed the mixing process in about half the time and with about half the power required for the original gate-blunger. Coarse material is removed by sieving through lawns, usually made of metal, which are now agitated by a high frequency vibrator. To remove iron from the suspension it is passed over electro-magnets, though the old-fashioned horseshoe magnets are still in use. The purified suspension is then freed from its excess of water by being pressed through cloths made of cotton. The filter-press was introduced in 1856. The plastic clay mass is next brought to the correct uniformity of texture in what is called a 'pug' mill, the latest form of which (the de-airing pugmill) is of recent date.

The subsequent manipulation of the purified plastic clay has been mechanised. Throwing on the wheel though still practised has been largely replaced by mechanical processes lending themselves more readily to mass production. The manual dexterity and speed of a skilled

thrower are very great but cannot produce the quantities required at the necessary low price. The processes of 'jiggering' and 'jolleying' by which plates and cups are shaped have been speeded up by the use of power-driven machines and here again William Boulton introduced improvements. Still further improvements were made by the introduction of the 'batting' machine which produces the batt or pancake to be shaped subsequently on the jigger.

Automatic machines for the manufacture of dust-pressed articles, e.g. tiles and the complex shapes (made from powdered materials) required by the electrical industry, were introduced in the middle of the 19th century.

*Casting slip*

From a scientific point of view the most revolutionary innovation during the past century has been the use of alkaline casting slip. In place of the laborious process of building up large articles by pressing, complex shapes can now be cast in moulds satisfactorily by the use of alkaline slip. In the investigation leading to this form of slip, Brogniart played a leading part but early in the 20th century Mellor and others did notable work.

*Glazes*

Grinding is a very important matter not only for producing clay dust of correct particle size for tile making but also for the preparation of glazes. Cylinder grinding by pounding the material with pebbles in a rotating drum was introduced in 1869 by Alsing and a form of it in which water is used is now almost invariably adopted for the preparation of glaze materials.

The preparation of glaze material was greatly influenced by a report by Thorpe and Oliver to the Home Office in 1898 on the subject of lead poisoning arising from the extensive use of lead glazes. As a result 'fritted' glazes were introduced, a process by which the raw glaze materials are first fused together and then pulverised. Felspar may be termed 'Nature's frit'.

*Decoration*

The decoration of ceramic wares takes many forms. The glaze, primarily intended in the low fired wares to make them impervious to water, may be coloured or various effects produced in the general glaze by firing. The special effects produced by Burton and the 'flambé' glazes of Bernard Moore are recent developments. But the main forms of decoration of the wares in common use are either under-glaze

decoration on the biscuit (as the fired but unglazed body is termed) by means of transfers, lithograph or hand-painting, or on-glaze decoration by similar processes after the biscuit has been given a coating of glaze.

Under-glaze printing was introduced here about the middle of the 18th century. The transfers are made by printing them, and the first machine for pottery printing was devised in 1831. The on-glaze printing is generally confined to lithographic transfers. These two methods account for the decoration of the mass-produced wares in common use. The elaborate china wares such as costly dessert services are entirely hand-painted in enamel colours, generally as on-glaze effects. Recently there has been a revival of free-hand painting to cater for less expensive markets.

Special forms of decoration, of early date and still famous, are the Wedgwood wares with figurines applied either to the body or glaze, and either in opaque or translucent materials; and the *pâte sur pâte* technique with which the name of M. L. Solon of Mintons is associated. The most modern form of decoration which has hardly passed the experimental stage is decoration by the application of plastics on the biscuit. Cheap artistic ware may be made on this basis in increasing quantity in the future. The appreciable moisture expansion of many plastics produced at present and their tendency to break up under heat and in contact with grease, etc. rule out the use of these plastics for domestic wares.

### *Firing of the wares*

The methods of firing are important and perhaps the greatest advances in recent years have been made in this direction. The most important is the introduction of continuous firing in the tunnel kiln. Although a good deal was known of the possibility of this method and the first British patent was taken out in 1858 it was not until 1910 that a really workable system was devised by Dressler. Since World War I an increasing number of tunnel kilns have been built in this country and their heating greatly increased the use of gas and electricity. In North Staffordshire alone the consumption of town-gas rose from 19 million cubic feet in 1920 to 1,400 million in 1940. During the same period the consumption of electricity in the same area rose from 3·8 million to 11·6 million units. In 1939 Messrs. Wedgwood built a new factory which is all-electric, the biscuit and glost kilns being constructed on this principle. The thermostatic control that can be used with these forms of firing in a tunnel kiln is a great safeguard against firing failures.

Thermal control has been, and still is, largely secured by means of 'seger' cones which were devised by Seger in Germany in 1886 (see also p. 148). They have been developed and manufactured here since

World War I when the German source ceased to be available. Under the direction of Dr. Mellor at the North Staffordshire Technical College satisfactory cones were produced and the process was taken over by Messrs. Harrison of Hanley in 1938. The standardisation of the cones has been materially assisted by collaboration between Stoke and the National Physical Laboratory. Other types of ceramic heat-indicators are also widely used.

An important element in the firing of ceramic wares is the 'sagger', or protective container, in which the wares are placed to protect them from the direct heat of the kiln. The life of saggers, other than those used in the china biscuit ovens, has been increased by research from about five to about twenty firings. The investigation originally started by Mellor has since been developed highly successfully by collaboration between the British Refractories Research Association and the British Pottery Research Association. The cost of saggers and other kiln furniture is higher than is often realised and may be between half and three quarters of the cost of the fuel. Increased life of the sagger is therefore an important factor.

*Co-operative research*

During World War I an interesting research was put in hand with a view to producing from purely British deposits a satisfactory hard paste porcelain similar in character to the continental wares. The investigation was mainly financed by D.S.I.R. and conducted by J. W. Mellor in conjunction with Bernard Moore. The result was successful and samples of the ware produced may be seen in the museum of the North Staffordshire Technical College, but for one reason or another it has never been taken up or used generally by the industry.

The chief stimulus to the application of science to the industry in the early years of this century was the British Ceramic Society which provided a medium for discussion and interchanges of experience. It was also the source from which new knowledge was disseminated and Mellor was its main contributor. The pottery school at the North Staffordshire Technical College under his direction also trained men previously unavailable for the industry.

After several abortive attempts the British Pottery Research Association was formed in 1937 and is gradually securing the confidence and increased support of the industry. As will have been gathered the industry generally is at present hardly research-minded and the firms have but few men of science upon their staffs. Increasing use of science will have to be made however if the industry is to retain and expand its export trade, or even retain its hold on the home market. The Research Association needs to be put on a radically different financial footing and

it is encouraging to know that the industry is alive to that necessity. The total income of the Association in 1942 was only £14,000. In 1943 it rose to £25,000 and an income of £40,000 is now assured. Such an expenditure on research and development for the industry as a whole is not large when at a conservative estimate manufacturing losses amounting to between one and two million sterling are incurred annually. Much of this loss might be avoided.

# CHAPTER 20

# PRINTING

### *Historical*

Europe cannot claim to be the first discoverer of transmitting knowledge by the aid of the printed word. Printing from wood blocks was an established practice in China in the 10th century and less widespread use of the process in that country can be traced from about the end of the 6th century.

It was not until five hundred years later that the art was rediscovered in Europe. The credit of that rediscovery belongs to Gutenberg who at Mainz, in 1445, invented a press by which a sheet could be printed on both sides (the Chinese method allowed for printing on one side only), a type mould for casting separate letters to align and fit accurately and a viscous ink to transmit the impression to paper. In the press used a platen or plate pressed the paper against the inked type, by a screw working through an upper beam. Some thirty years later, Caxton in 1476, set up at Westminster the first printing press in this country based on this principle.

During the 16th–18th centuries various improvements were made, chiefly in Germany and Holland, and the first iron hand-press in place of a wooden one was constructed by Haas of Basle in 1772. It was probably on this device that the Earl of Stanhope, F.R.S., in 1798 invented the first commercial iron printing press. The screw principle was used but a system of levers increased the pressure and distributed it more evenly over the platen. William Nicholson, an Englishman, first suggested the use of a cylinder, in place of a wholly flat mechanism for pressing the paper against the inked type. He did not develop the idea and it was left to Koenig, a German, in 1811 to invent the first cylinder flat-bed press worked by steam power. The invention was developed in Bolt Court, London, with the aid of another German (Bauer) domiciled here, and was used by *The Times* newspaper in 1814. A rate of 1,100 impressions an hour could be obtained from it. A few years later the 'perfecting machine' was evolved which, by the use of two cylinders and two type 'formes', could print on both sides of the paper in the same machine. Koenig again was largely responsible for its initial stages.

### *The rotary machine*

A great advance was made, especially for newspaper production, by the invention of the rotary machine and the introduction of the stereo-

typing process adapted for casting curved plates which were fixed to a rotating cylinder. In 1846 Hoe, an American, invented the rotary and two years later Applegarth, after many experiments in this country, constructed the first rotary press for *The Times*, which produced 8,000 copies an hour. In 1868 the Walter press was built, using curved stereos on the cylinder and a continuous web of paper. It is on the model of this initial machine that newspaper printing presses have been developed in this country. Improvements were gradually made, largely in America, and Hoe in 1887 introduced a machine capable of printing a 16-page newspaper at the rate of 12,000 an hour. The foregoing are some of the landmarks in the evolution of letterpress and newspaper printing presses which, with other mechanical inventions mentioned later, have led to the mass production of books and newspapers and brought them within the reach of the common man.

### *Stereotyping*

Stereotyping is one of a number of important related processes and the Earl of Stanhope, in 1800, may be regarded as the pioneer in using the plaster of Paris process. The inventor of the wet 'flong' process is in doubt. It consists of making a mould of the type forme in *papier maché* from which printing plates are cast in molten metal. A number of casts can be obtained from one mould so that duplicate plates can be made. Recently work has been done on making stereos and printing plates in plastics and this country has not been backward in this development. Their lightness compared with metal plates is an obvious advantage but there are certain technical difficulties still to be overcome.

### *Electrotyping*

Another method of duplicating printing plates is by electrotyping, in which a mould of the original is taken in wax rendered conducting with graphite, or in sheet lead with copper or nickel-electro deposited on it. When the deposited metal film is about 0·006 in. thick it is removed from the mould and backed up with molten metal (lead-antimony-tin alloy). This process was invented in the 1830's by Jacobi, an English architect living in St. Petersburg. Spencer in Liverpool and Adam in New York were also early workers in this field. Plates are now frequently chromium faced to give them longer printing life.

### *Type composing*

Composing machines by which the type is set for printing are of two kinds, those for setting single letters and machines which assemble the matrices of letters into lines and then cast lines of type. The monotype machine developed in America about 1887 was of the first, and the

linotype, as its name implies, is of the second kind. The first type-composing machine patented in England was by Church in 1882 and was of the first single-letter kind. In 1797 Herman had set up matrices of copper in page form and made a cast from them. This may be regarded as the earliest forerunner of the linotype machine. The linotype was due to Mergenthaler of New York and was first put into successful commercial practice in 1886.

During the inter-war period machines were developed on the basis of photo-composing, i.e. producing a photographic negative of the type page and these may lead to further changes in type-setting. The most recent development of all in composing machines is the teletypesetter in which type is set as the result of an impulse sent by telegraphy. The teleprinter is a British invention referred to elsewhere (p. 206). The so-called radio newspaper is another way of transmitting and recording news by radio. Most of these recent developments have been made in America.

*Type and type founding*

Type and type founding, though perhaps more properly considered industrially under non-ferrous metals, may be mentioned here. Type metal is an alloy of tin, lead and antimony. The earliest printers made their own type faces and up to about 1720 this country imported its type, largely from Holland. William Caslon, however, about 1720 produced a type superior to that previously imported and from that date till 1780, few books were printed here except by means of it. Since that date, many beautiful type faces have been designed in this country.

*Use of photography*

With the development of photography during the 19th century its capabilities for adding to the power of illustrating the printed word were also exploited. The original illustration is photographed and the negative so obtained printed down on to a copper or zinc plate coated with a layer of fish glue rendered light sensitive with bichromate. Where the light passes through the negative the bichromated colloid is hardened and remains on the plate after washing in water. It is further hardened by heating and then acts as a 'resist' when the plate is etched with nitric acid (in the case of zinc) or with ferric chloride (in the case of copper) leaving the image in relief. Where continuous tone originals are to be reproduced a halftone screen is placed in front of the negative before exposure and a halftone negative, i.e. one in which the tones of the original are broken up into dots, is obtained. This is then printed down on to metal and the plate produced in zinc or copper as previously described. The beginnings of the process were made in the middle of

the 19th century but it was not developed until the 1880's and the names of Meisenbach and Levy of the U.S.A. are chiefly associated with it.

*Coloured reproduction*

In 1892 a method of reproducing coloured originals was developed by Kurtz and Ives of Philadelphia in the form of the three-colour process in which three negatives are obtained from the original through different coloured filters. Each negative is made into a separate printing block and printed in the respective colours one after the other. Naturally accurate registration is necessary to secure a completely successful result. The process was later extended to include four colours—a yellow, red, blue and black printing plate.

*Lithography*

Lithography, the process by which the majority of posters, show-cards etc. are produced, and which is also used for the decoration of tins, was discovered in 1796 by Senefelder in Germany. The essential feature of the process as originally invented is that a smooth clean block of limestone has the printing image drawn on it in an oily ink. The remainder of the surface is then rendered unreceptive to oily ink by coating with a solution of gum arabic. To obtain prints the plate is rolled over with a damp roller which wets the gum arabic film but not the oily image, and this is immediately followed by a roller charged with oily printing ink which does not adhere to the damp gum arabic film but does transfer ink to the oily image. When paper is pressed against the latter, a print is obtained. Today the use of limestone as the printing base has been largely discontinued. Zinc plates (introduced about 1885) and aluminium plates (1890) have taken its place. From about 1850 onwards, photographic methods using bichromated colloids (gelatine and albumen) were introduced. Most of these methods were of continental or American origin.

In the decoration of tins the offset principle is employed, i.e. the printed image is transferred from the printing surface to a rubber blanket and thence to the tin. Between 1880 and 1890 this offset method was applied to paper printing and is the method by which the bulk of lithography is done today.

*Photogravure*

The other major printing process is photogravure, used largely for the printing of illustrated magazines, etc. In this process the design to be printed is etched into the surface of a smooth copper cylinder which rotates in a bath of fluid, volatile ink. A steel doctor-blade wipes the ink from the surface of the cylinder, leaving the ink in the etched recesses of

the image. The process in its present form was invented by Karl Klic in Germany about 1880, following on earlier work by Fox Talbot and Sir Joseph Swan in this country, Albert in Munich and Edwards in the U.S.A.

### *Printing ink*

Ink for printing is an important section of the trade. It was made in very early times in China from lamp black and used for the early wood block printing. Carbon mixed with linseed oil, varnish or mineral oil is also the source used in Europe for black ink. For coloured inks, mineral and lake colours are used. The most recent developments have been in connexion with the quick drying of ink by using special solvents and by the use of thermoplastic inks which set on cooling.

### *Binding*

An important element in the mass production of printed books is the folding of the pages, their gluing and stitching and finally their casing in cloth-covered strawboards. To Leighton, about the year 1822, is given the credit of introducing cloth covers but an American source attributes their first use to Lawson, an American. This method of binding was a considerable step in the mass production of books.

As will have been gathered, the printing industry has many aspects—paper-making on a commercial scale, naturally an essential element, has been dealt with earlier (Chap. 16).

### *Co-operative research*

When the industry in 1930 decided to form a Research Association it took as its title the Printing Industry Research Association. Its initial stage is interesting because it was different from that of any other grant-aided Research Association. It started as a technical consultative bureau, without State financial assistance, to supply by correspondence and by means of a technically qualified staff, answers to technical difficulties experienced by its subscribers. The subscription required was a minimum of one guinea. The underlying idea was that by such means a wide range of subscribers over this many-phased industry would be secured and that their interest in the possibilities of the greater application of scientific knowledge to the processes employed would be fostered. The end in view was achieved in a measure and subscribers found the bureau more than helpful to them. It was decided in 1935 to put the organisation on a radically different footing; its title was then changed to the Printing and Allied Trades Research Association and laboratories and staff were acquired for experimental work. The initial basis of finance was a stumbling block. Firms

accustomed to paying a guinea or two hesitated to pay ten or twenty times as much for a larger service of which they were at first sceptical. Influential leaders in the industry had a difficult task in bringing about the necessary change of view and the rate of growth of the Association has been impeded by its origin.

The important industry concerned with packaging has recently decided to join forces with the Printing and Allied Trades Research Association and to place the organisation on an extended footing to cope with the added problems involved. There are good grounds for hoping that the Association, enlarged as it now will be in new quarters at Leatherhead (see Appendix IV), will grow in size and importance. The closely connected industry—that of paper-making—has formed its own Research Association very recently and co-operative work between the two bodies is likely to take place.

The following are examples of achievements of the Printing and Allied Trades Research Association:—As a result of a study of the scientific principles underlying lithographic printing, improvements have been made in the process which will enable photo-litho plates to be produced many times more quickly and more economically. The solution of several thousands of special problems submitted by member firms has been a service of considerable commercial value to the industry. But above all the work of the Association has enabled the printer, the papermaker and inkmaker to meet on common ground to discuss their technical and scientific problems.

# CHAPTER 21

# PRODUCTION ENGINEERING

### *Nature of the science*

Although production engineering can hardly be termed a manufacturing industry, it is such an essential element in large scale production that a brief note upon it and upon machine tools is necessary in this Part of the book. Mass production is becoming of increasing importance to most branches of industry and has been largely advanced by the demands of war when enormous quantities of numberless articles and components are needed for its successful prosecution. Under peace conditions also, mass production has become an essential feature of modern development.

The production engineer brings to bear careful planning, good tooling and efficient lay-out of the workshops into a scheme of manufacture. By the provision of special jigs, fixtures, tools and gauges the production engineer can greatly simplify production and accelerate its progress as well as reduce costs. He is the skilled technical organiser, and by his work may well convert an uneconomic into a profitable proposition. His job is to see that the best design is used for the end in view and not merely to ensure that the components are satisfactory and their assembly correct. A modification of the design of a machine may greatly cheapen production without any loss in efficiency; the necessary jigs and tools to be used may also be profitably redesigned from a draughtsman's first drawing. The lay-out of a factory has to be considered. The grouping of the shops concerned with various stages of production needs looking at from an engineering point of view to ensure the least possible delay in the sequence of operations.

### *Origin of mass production*

America is generally regarded as the cradle of mass production, but in France at least two centuries ago the plan of making interchangeable components for firearms was in operation. Whitney, however, subsequently laid the foundations of mass production in the U.S.A., also in the first instance for making firearms, and their armouries were the source of the American machine tool trade. Naturally, the size of the home market in the States encouraged, under peace conditions, the rapid extension of large scale manufacture of machinery of all types and of consumer goods such as sewing machines, clocks and motor cars. In this country also, mass production has become of in-

creasing significance, and for its successful operation the technical science of production engineering is of first importance.

Successful mass production depends on the correct manufacture of identical components making up the machine or other product as a whole. Every one of, say, the hundred components of a machine must fit any other component with which it has to be conjoined without filing or other adjustment. Many of such components must be accurate to, say, two thousandths of an inch; some need a lower, some a higher tolerance. Unless the components are made with the necessary accuracy, effective and economic mass production is not possible. Measurement therefore, has to be an exact science and it has been made so by the work of Whitworth (1803–87), Johanssen the pioneer of the slip and block gauges, and the department of metrology of the National Physical Laboratory. To this last agency and its like in other countries, successful mass production is mainly due, for they have provided its fundamental basis.

The whole object of mass production is to allow comparatively unskilled labour to perform the bulk of the work. If a highly skilled mechanic 'sets' a machine—whether it be a capstan lathe, a drilling or a milling machine—and an equally skilled mechanic is responsible for the correct sharpening of the essential cutting tools, the work of actual production can be performed by relatively unskilled labour.

During the last twenty years the Institution of Production Engineers has done much to develop this important new technical science, and it is not too much to say that the successful prosecution of World War II was largely due to the work of production engineers in the layout and establishment of factories in this country and in the United States to meet the enormous demands for every type of machine and tool. 'Give us the tools and we will finish the job' was a true saying of the Prime Minister but it had to be implemented in large measure by the production engineer.

### *Machine tools*

There are many hundreds of separate types of machine tools used in engineering practice and the following are the main classes:—Lathes, drilling and milling machines, gear cutting machines, grinding machines, mechanical saws, punches and shearing machines, hammers and presses, and portable tools of many descriptions. These and all forms of vices and wrenches, together with wood working machines, form the indispensable equipment for large scale production and for precision work. The term machine tool is usually taken to mean any power-driven apparatus for working in metal. The lathe is the king of machine tools but machines for planing, drilling and stamping are very important.

The true and first inventor of the lathe is unknown, for it finds its origin in the potter's wheel which was used before the Christian era. Machine tools in the modern sense were first invented and made in this country. To take but one example, J. Nasmyth in 1839 invented the steam hammer, of great importance in early shipbuilding. He also invented a planing machine, a nut-shaping machine, a steam pile-driver and hydraulic machines for various purposes.

In more recent times this country has fallen behind the U.S.A. and Germany both in the size of its machine tool industry and in the types produced. We have been particularly weak in tools for special purposes and in automatic types. This fact was brought out during the rearmament period prior to World War II and subsequently. In 1933–35 our exports of machine tools increased in value from £1,265,000 to £2,246,000, but our imports doubled in value from £853,000 to £1,698,000 and more than doubled in quantity. Moreover the average value of imported machine tools at that time was £220 per ton while the average value of exported machine tools was £136 per ton, showing our dependence on the U.S.A. and on Germany for the more advanced and costly types.

This country has been slow since the turn of the 20th century to mechanise its industries compared with the U.S.A. and Germany, and in those countries many operations are performed by machinery which here are done by hand; for instance the percentage of automatic looms in the American cotton industry compared with that in this country is striking (see p. 172). The development of products such as motor cars, refrigerators and domestic machinery of all kinds has proceeded on mass production lines abroad and has involved complete mechanisation. The replacements of machinery in the U.S.A. are much more frequent than here. On the other hand it must be remembered that for the production of goods of the highest class with a relatively small market, mass production methods are unsuitable and economically unsound, as for instance in the manufacture of luxury textiles or luxury motor cars. It is in these directions that competition in overseas markets is least severe. The failure to make replacements here on the scale adopted in the U.S.A. is due in part, no doubt, to the refusal until recently of the Inland Revenue authorities to admit for income tax purposes adequate depreciation allowances in respect of many types of machinery. But it is also due to a native reluctance to replace machinery until it is completely worn out. The practice of 'making do' continues until a position is reached when complete re-equipment is called for, involving great capital outlay.

So far as the British machine tool industry is concerned it cannot be said that it is, under normal conditions, of the size and nature needed for the engineering and machine tool-using industries of the country. Those industries have found themselves largely dependent on imports

for their machine tools and particularly for those of specialised and advanced kinds. The demand for the latter is limited and the using industries have found it cheaper and better to import special tools from abroad. Protection and the size of the home markets in the U.S.A. and Germany enabled machine tool makers there to produce more cheaply, and though protection here during recent years has helped, the position has been difficult. The industry is fairly widespread but tends to be concentrated in Coventry and Halifax. The average size of the firms, with one or two exceptions, is small. Even well-known firms employ only 200–300 workers apiece.

British industry is under-tooled both actually and potentially. By that we mean many industries need re-equipment and the cotton textile industry is a case in point. But other industries owing to war conditions have been running their machinery to destruction. It is not only fatigued, it is worn out and its replacement will involve large expenditure. It is doubtful if British plant manufacturers and machine tool makers are in a position, save in small part, to supply the new equipment needed.

Machine tool makers and plant manufacturers in this country have been more inclined to copy foreign ideas, with or without modification, than to think for themselves. A flourishing and healthy machine tool industry is essential for a first class military Power; it is equally essential for a manufacturing nation dependent on a large export trade for its existence.

### *Co-operative research*

Research in production engineering problems has been undertaken by the Institution of Production Engineers at Loughborough since 1938. Before that little or no research had been done in this country since Professor Dempster Smith's work on cutting tools at the Manchester College of Technology. This neglect of research is remarkable in view of the growth of quantity production and of developments elsewhere in production technique during the last 25 years. The production engineer is not himself an inventor or a tool designer. He knows what is needed to produce the results he aims at and can say what he wants; but research and experiment are needed to meet his requirements. The work of the Institution of Production Engineers has not been directed primarily to the design of machine tools but rather to the best use to be made of them.

There is need in this country for far more research in production engineering and machine tools and it is satisfactory to know that a considerable extension of the present work is in contemplation. A Research Association is being formed to link up the work of the Institution of Production Engineers with that of the machine tool makers, the makers of gauges, precision tools and engineers' tools and the users of their products.

# CHAPTER 22
# REFRACTORIES

## *Nature of materials*

Refractories are the heat-resisting materials essential as furnace linings for the production of iron and steel, non-ferrous metals, glass, gas and coke. The failure of these linings not only involves the cost of the replaced bricks but the much greater loss due to the furnace being out of commission while they are renewed or repaired. The importance of refractory materials to heavy industry was clearly recognised by Sir William Siemens when he wrote, 'Every advance made in the quality of refractory products has been attended by an improvement in all manufacturing processes dependent on furnace operations.' To achieve this advance, the geologist, physicist, chemist and engineer must all play their part.

The essential characteristic of a refractory material is its ability to withstand high temperatures without suffering undue deformation or softening; raw materials having this property include fireclays, certain silica rocks, magnesite, chromite, dolomite, sillimanite, andalusite and kyanite, bauxite and other less common materials. Of these, fireclay is the most widely used, and over four-fifths of the tonnage of refractory materials made in this country is of this type. Fireclays, however, differ widely in composition and physical properties, and a knowledge of their differences in behaviour is an essential part of the technical experience of the industry.

## *Historical*

The necessity for refractory furnace linings must have been realised from the Bronze Age, for the extraction of the metal would require a furnace, however crude it may have been. There can be little doubt that clays and sandstone boulders were the first refractories to be used. In England, the Romans used refractories for metal extraction, and the remains of their brick kilns have been found in close proximity to their workings for lead. Little is known of the use of refractory materials in mediaeval times, but towards the middle of the 16th century skilled glass-workers from the continent settled in Stourbridge and there discovered suitable fireclay with which to make their glass-pots. The Stourbridge fireclay soon became widely known; in the 18th century the annual output of fireclay from this district was about 4,000 tons; in 1850 it was 45,000 tons, while by 1875 the yearly output exceeded 200,000 tons.

The Sheffield area has been noted for its ganister. This highly siliceous rock was first used by Huntsman, in the latter half of the 18th century, for his crucible steel process. When, in the last century, Bessemer introduced his converter process, the consumption of Sheffield ganister was greatly increased. The open-hearth method of steel-making, introduced by Siemens in the mid-19th century, depended for its success on the production of silica bricks—the Dinas brick—which were first made in South Wales. In Scotland the refractories industry may be said to have begun with the opening of the famous Glenboig seam of fireclay in 1836.

In following the concurrent extension of technical knowledge, it must be remembered that, before the early part of the last century, fireclay was the only refractory material in extensive use. This being so, the earliest technical knowledge must be sought in the clay industry, amongst the pioneer potters of North Staffordshire. Josiah Wedgwood studied the effect of heat on clay and used its tendency to contract as a measure of temperature; a paper on the 'pyroscope' was presented to the Royal Society in 1782. Wedgwood also studied the fusion points of ceramic mixtures moulded in the form of prisms. Such mixtures were, a century later, used by Hermann Seger as the basis of his pyrometric cones. This German technologist, during the latter half of the last century, studied the constitution of clay and the effect of heat on the breakdown of the clay molecule, the influence of kiln gases on the properties of the fired ware, the theory of dryers and kilns, and other problems. In the more specialised field of refractory materials Seger was chiefly interested in the fusibility of clays. In the first half of the 20th century, J. W. Mellor occupied a similar leading position in the field of ceramics and refractories. As the first director of the British Refractories Research Association, and as honorary secretary of the British Ceramic Society (to which he contributed over a hundred papers), Mellor was instrumental in furnishing the industry with essential scientific data which have profoundly altered its outlook.

### *Constitution of clay*

It was realised at a very early stage that the technical advance of the ceramic industry depended on a fuller knowledge of the raw materials used. The study began by way of chemical analysis, and in 1835 the formula $Al_2O_3 . 2SiO_2 . 2H_2O$ was proposed for pure clay. It was soon realised, however, that clays vary too greatly for them all to be included in this simple formula, but the efforts of chemists to solve this difficulty were misplaced; during the last decade of the 19th, and the first decade of the present century, a spate of constitutional formulae appeared based solely on the requirements of valency. Clays from different

localities had received mineral names quite early in the last century, and the distinction between them was loose. Thus, nacrite was named in 1807; allophane in 1816; halloysite in 1826; montmorillonite in 1847; and kaolinite in 1867. The significance of these minerals was small until the development of X-ray technique offered a method for their structural examination. Sir William Bragg subjected samples of china clay, purified kaolinite, and sillimanite to X-ray analysis in 1922, and proved that china clay contains an important amount of kaolinite. C. S. Ross and P. F. Kerr, working in America in 1930, proved the distinction between nacrite and kaolinite, and also showed that potash-bearing clays are distinct from montmorillonite. Progress has since been rapid and the structure of clay minerals as distinct from their chemical composition is now appreciated by scientists in the ceramic industries as their significant characteristic.

A still newer tool which has been applied to the study of the clay minerals is the electron microscope. With this instrument it has been verified that kaolinite and dickite occur as overlapping hexagonal plates; halloysite, on the other hand, occurs as rod-shaped crystals; the montmorillonites show structures ranging from ill-defined to extremely thin plates. This accession of knowledge is already being applied in industry; and both the chemical and physical characteristics of the individual clay minerals are at last becoming known.

*Effect of heat on clays*

On calcination, clay passes through a state of mechanical weakness before developing strength due to vitrification. These phenomena received attention from the master potters of the 18th century, but thermal analysis, in the modern sense of the study of endothermic and exothermic reactions, was not applied until 1887, when H. le Chatelier observed a retardation in the heating curve of kaolinite at about 550° C., and an intense acceleration in the rise of temperature at about 1000° C. These observations were confirmed by J. W. Mellor in 1910, who considered that the simplest explanation of these effects was to assume a breakdown of the clay molecule in the region of 500° C. giving water evolved as vapour, free silica and free alumina; the exothermic effect at 800°–1000° C. was attributed to a physical change in the free alumina; on further heating, the free alumina and silica were considered to recombine to form mullite.

A new line of approach was made in 1927, when A. E. MacGee pointed out the influence of these thermal phenomena on the 'over-all' specific heat of a clay. In heat calculations on kilns prior to MacGee's work, a specific heat figure which excluded the thermal effects was used, leading to serious error. During the past decade, as the complexity of

the mineralogical constitution of clays has become more fully appreciated, thermal analyses have been made with a view to distinguishing between these minerals for the purpose of a general study of clay as such. This work has now become sufficiently advanced for thermal analysis to be used, in some laboratories, as a control method.

*Application of equilibrium diagrams*

Mellor described the firing of clay wares as 'the chemistry of arrested reactions'. The probable course of these reactions is indicated by the phase rule and the appropriate equilibrium-diagrams. Several phase rule investigations have been of major importance in the field of refractories; they have formed a more scientific basis on which to control the firing process and have aided in the selection of refractories to resist specific slagging agents. Much of this work has been carried out at the Geophysical Laboratory, Washington, to which the world owes a great deal.

In this brief review, but two examples of the application of these researches can be given. The classical work of H. le Chatelier on the polymorphic transformations of silica, was followed in 1913 by Fenner's silica equilibrium-diagrams; this made clear the course of the transformations from quartz to cristobalite and tridymite which occur during the firing and subsequent use of silica bricks. Greig's later work on immiscibility in silicate melts demonstrated the adverse effect of alumina, alkalies and certain other impurities on the properties of silica refractories. The second important example of the application of phase rule data to this industry is in the field of alumino-silicate products; the work of Bowen and Greig, carried out some twenty years ago, on the alumina-silica system, has had a profound influence on the refractories industry.

*Co-operative research*

The shaping of bricks is dependent either on the plastic nature of clay, or on the cohesion of powders under high pressures. The British Refractories Research Association at Stoke-on-Trent has devoted considerable attention to both processes. The study of plasticity began by simple experiments on the deformation of clay-grog mixtures (i.e. mixtures of fired and un-fired clays) but has since been extended to a full study of the clay-water relationship. This research has a close bearing both on the shaping of clayware and on the drying process; the efficiency of dryers has also been examined.

*Kiln efficiency*

The fuller application of the principles of fuel technology to kiln firing offered prospects of immediate fuel economy in the early days of

the Research Association. Detailed heat balances were therefore made of different types of kilns and their thermal efficiencies were compared; on the basis of the experience gained, the British Standards Institution has since drawn up a standard code for use in the determination of kiln efficiency. Firing schedules, however, must be based on a complete knowledge of the changes brought about in the raw materials; hence the rate of elimination of carbonaceous material from fireclay blocks on heating, and the temperature gradients set up within the blocks, have been examined. Another aspect of kiln firing is the reduction of smoke emission; kiln design and firing technique have been modified to achieve this end.

### *General properties of refractory products*

Twenty-five years ago, when the Research Association was formed, the properties of refractory materials had not been accurately evaluated, and even the methods of testing to be adopted for such an investigation were but partially developed. Studies have therefore been made of intrinsic properties such as refractoriness and refractoriness-under-load, spalling resistance, gas permeability, the action of slags and gases, etc. This information has since formed a basis on which to carry out work of closer application to the user.

Much of this research has been carried out on fireclay products. In the field of silica refractories, considerable attention has been given to the effect of mineralizers on the rate of quartz conversion; the after-expansion of silica bricks, their spalling tendency, and thermal properties have also been investigated. The Research Association studied at an early date the development of composite chrome and other types of basic refractories. During World War II an intensive study has been made of the constitution of basic refractories. These may contain a number of minerals. Many of them have been synthesised and their properties have been individually studied. The work has thrown considerable light on the behaviour of these refractories in metallurgical furnaces. Close attention has also been paid to the development of improved insulating refractories and of jointing cements.

### *Utilisation of refractories*

The trend of most industrial processes has been towards increased rates of working. In the case of industrial operations involving heat, increased output has, in general, been achieved by the use of a higher working temperature; hence the demands made on refractory materials have increased considerably. The blast furnace offers an excellent example of this trend. A century ago, these furnaces were hand-charged and the air-blast was not preheated; outputs were small and the furnace

lining frequently lasted twenty years. The introduction of hot-blast and mechanical charging immediately stepped up the rate of working, but the refractory lining was called upon to withstand not only a higher temperature, but a more fluid slag, increased erosion by the blast, and aggravated abrasion by the more quickly descending burden. The average life of the lining in consequence has decreased but the refractories are now dealing with a far greater tonnage per unit of brickwork than was formerly the case.

Increasingly severe conditions occur in other industries. In the steel industry, the operating temperature is now dangerously close to the fusion point of the silica refractories used; in the carbonising industry, the fireclay retorts formerly employed have had to give place to silica and semi-silica materials; boilers are now operated at extremely high pressures, necessitating the use of aluminous firebricks and extensive water-cooling; in the glass industry, tanks are 'pulled' far faster than hitherto and the fireclay blocks formerly used have been replaced by sillimanite. The position is being met by a closer study of the service conditions, and by deeper research into the fundamental properties of the refractory materials used in furnace construction.

# CHAPTER 23

# RUBBER

When seedlings of *Hevea brasiliensis* were raised at Kew, during the Directorship of Sir Joseph Hooker, from Brazilian seed collected by H. A. Wickham in 1875–6 and introduced into Ceylon and Singapore, an industry was founded which has grown into great importance. The cultivated plantation rubber is superior to most wild rubber and the spread of its propagation may be judged by the following figures. At the end of 1936 the total area planted with rubber throughout the world was approximately 8,433,000 acres and of this area some 4,470,000 acres are situated in the British Empire.

## *Vulcanisation*

Apart from the widespread cultivation of plantation rubber, the most important basic discovery from a manufacturing point of view was vulcanisation. Sulphur brings about chemical cross-linking of the thread-like caoutchouc molecules into a network and also to some extent combines with caoutchouc, the essential hydrocarbon constituent of rubber. Vulcanisation modifies many of the properties of rubber. Caoutchouc is fairly soluble in many solvents, while vulcanised rubber is insoluble in nearly all, though many are readily absorbed and cause the rubber to swell. Caoutchouc is easily softened and rendered sticky by a rise in temperature to no more than summer heat, and is stiffened by freezing, while vulcanised rubber is much less sensitive to such changes. Vulcanisation also renders rubber more elastic and less plastic than caoutchouc. If vulcanisation is continued to a stage approaching 30 per cent of combined sulphur, a horny black substance is formed known as ebonite or vulcanite, largely used for electrical insulations and other purposes.

Vulcanisation was first discovered accidentally by Goodyear in 1839 and he perfected and patented his process in 1844. Hot vulcanisation with sulphur was also discovered by Hancock in 1843 in this country, and Parkes in 1846 discovered a cold vulcanisation process, using sulphur chloride. Much later (1918) Peachey in this country invented his cold dual gas process by which vulcanisation was effected at ordinary temperatures by treatment of the caoutchouc with sulphur dioxide and hydrogen sulphide. The majority of industrial productions from rubber depend on vulcanisation for their effective usefulness, and apart from

Goodyear's initial discovery many developments of the process are due to British scientists.

*Tyres*

In the application of rubber to industrial purposes, the development of tyres is probably the most important. In 1845 Thomson was granted the first patent for a pneumatic tyre, using an inner tube of rubber and a cover of leather impregnated with rubber solution. In 1888 Dunlop invented his pneumatic tyre and in the following year Bartlett the clinch-on type of attachment for tyres. Four years later Palmer invented weftless (cord) tyre fabric. Balloon tyres were introduced in 1923 in which the air pressure was reduced from 50–55 lbs. to 32–36 lbs. The introduction of this type brought about much greater comfort to users of motor cars and reduced materially the maintenance costs of cars by reducing the vibration.

It is perhaps not realised what an effect the introduction of the pneumatic tyre has had not only on the use of the motor car but of the aeroplane. The landing gear of the modern aeroplane would have presented a very difficult problem without it. All runways would have had to be surfaced like a first-rate concrete road; while landing in the rough would have meant disaster. Aerial navigation might have depended mainly on the flying boat. Similarly balloon tyres are essential for military vehicles, for without them the crossing of the sand hills in the North African desert would have been impossible.

Some indication of the results of the continuous research and development on the improvement of tyres is given by the following facts. The average life of a rubber tyre at the end of World War I was just under one year: in 1939 it was three years. Or putting it another way, a tyre in 1920 had a distance life of 5,000 miles and in 1939 one of 15,000 miles. The average cost per day per tyre at the end of World War I was about 48 shillings: in 1939 it was just under 4 shillings. The motor-car industry has been greatly benefited by the work of the rubber manufacturer.

*Other industrial uses*

Ball games in this country have also benefited from the efforts of the rubber manufacturer. Golf balls and tennis balls are examples. Haskell produced the first 'rubber cored' ball in 1898 to replace the old 'gutty' ball made of solid guttapercha. Various improvements have been made since that date with the consequent necessity of remodelling golf courses to meet the added efficiency of the balls and clubs used.

The industrial uses to which rubber is put are very considerable. In 1859 Hooper used rubber for the insulation of electric wires for the

first time, while ebonite or vulcanite has been developed for a variety of insulating purposes. It used also to be largely employed for the making of dentures.

Rubber is of considerable importance for footgear, either in the form of complete protection or for soles and heels of leather shoes, and for hose-pipe, while water-proofing of fabrics by rubber solutions for overcoats has made great strides. Other instances will be readily called to mind. In 1915 Schidrowitz and Goldsbrough in this country invented the manufacture of sponge rubber from latex, and in 1922 Kaye applied latex to paper manufacture. Rubber blocks for roadways have been tried and sheets for floorings with consequent deadening of sound are in great use. The increased use of rubber generally in industry, including that for tyres, is shown by the fact that while in 1914 17,000 tons were used, in 1939 the figure had risen to 1,227,000 tons.

In all these directions the larger rubber-goods manufacturing firms have played their part, and they maintain research and development departments. The Dunlop Company is the largest in this country and it dominates the industrial position, at all events so far as tyre manufacture is concerned. Several manufacturing firms obtain their raw material in part from their own plantations.

*Co-operative research*

Other important developments have occurred since World War I. In 1919 the Research Association of British Rubber and Tyre Manufacturers was formed. Although it has never had sufficient funds to create an adequate scientific centre for collective research it has helped scientific progress materially, and has been of special assistance to the smaller concerns. One of its outstanding contributions to the industry has been the formation and development of its Information Bureau which, it may safely be said, is the most complete organisation of its kind in the world. On the laboratory side, research has been conducted on oil-resisting rubbers, the nature and properties of ebonite, the effects of ageing testing methods and water absorption of rubber.

Here a digression must be made to describe the earliest attempt to put the finance of co-operative research for an industry on a statutory footing. In 1932 a Bill was introduced in Parliament to institute a levy on the whole industry for co-operative research, and at the outset the Bill was supported by an overwhelming majority of the industry measured by the capital employed. When the Bill seemed to have a good prospect of being placed on the Statute Book, dissension within the industry arose, the necessary industrial support for it was withdrawn, and the Bill was killed. The fact is mentioned because it shows how difficult it is to bring about by voluntary effort

within an industry a union of conflicting interests in support of a proposal which in the long run must redound to the benefit of an industry as a whole.

An important development was brought about in 1933 by the formation of the Rubber Producers' Research Association. About that date the producing countries of the world decided to institute research into new uses for rubber and in Holland an important institute was in existence for that purpose. The funds for the project were to be derived from a cess levied on the rubber produced. The British Rubber Producers' Research Association represented the British unit of an international organisation to be financed from the British portion of the general cess. Earlier, in 1922, a Rubber Research Scheme (Ceylon) had been established; and the Rubber Research Institute of Malaya was founded in 1925.

The planting research bodies have gone deeply into all matters of propagating *Hevea brasiliensis*, as well as into fertilisers, diseases, tapping systems, latex constituents, latex preservatives and concentration, variability of raw rubber, and plasticity. The British section of this international organisation (cf. International Tin Research organisation, p. 102) has an ambitious programme and is engaged on research into the constitution of the rubber molecule and the mechanism of aging. It is to be hoped that its operations will be still more closely linked with those of the manufacturers' Research Association.

*Synthetic rubber*

A new factor has recently appeared—synthetic rubber. In the early days British contributions to the study of synthetic rubber were of considerable value. In 1860 Williams first isolated and named isoprene and dipentene from the products of the dry distillation of rubber. In 1892 Tilden worked out the molecular structure of isoprene and first polymerised it to a rubbery material. In 1910 when Harries was attempting to establish his theory that rubber consisted of isoprene, polymerised to an eight-membered ring, Pickles made the first suggestion that it consisted of a long chain of isoprene molecules.

Owing, however, to the abundance of natural rubber, grown on plantations within the Empire, research on synthetic rubber progressed more rapidly in other countries. Germany, realising its dependence on foreign supplies, set about the production of a synthetic rubber and *Buna* was the result in 1934. It was far more expensive than natural rubber, but Germany was made more or less independent of foreign importations in times of emergency and the cost was regarded as of secondary importance.

In Russia also the quest for methods of producing synthetic rubber

was actively pursued as well as the cultivation of indigenous sources of supply. A variety of the common dandelion (*Taraxicum*) as grown in Russia was found to contain in its root a latex with a relatively high rubber content. As the species grows best in wild and inhospitable areas, and as labour for gathering was not difficult to obtain, the Russian powers of organisation soon found means of supplying a substantial part of its national needs in this direction. An experimental plot of the species has been grown at Kew.

On the capture by the Japanese of 90 per cent of the rubber producing areas of the world during the early stages of World War II, the Allies generally, and this country in particular, were placed in a very difficult position, and Great Britain and America found themselves for the first time short of supplies. Close collaboration between the two countries took place in this as in other matters, and America with its unrivalled capacity for large scale production began making synthetic rubber. It was a simpler matter, having regard to transport facilities, to import it to this country than to establish factories here, when industrial capacity was stretched to the limit in other directions. As a result of American enterprise and scientific research it is said that the consumption of synthetic rubber by the Allied Nations during the later years of World War II was comparable with that of natural rubber prior to 1939.

All the synthetic rubbers used in bulk are polymers, consisting of molecules of very long thread-like nature built up of small chemical groups, like the links of a chain. By far the most important is GR-S, similar to the German 'Buna S' rubber, the threads being built up from two carbon-hydrogen units, butadiene and styrene. The amount of this general purpose synthetic rubber is over 90 per cent of all production. The others are special purpose materials, for resisting attack by oils, solvents, tropical heat, and sunlight. They were GR-M, similar to 'Neoprene', made up from chlorbutadiene units; GR-P, similar to 'Thiokol', the long chains or threads containing many sulphur atoms; and SR-A, similar to the German 'Perbunan', made up of butadiene and acrylonitrile units. Various other synthetic plastics are used as substitutes for rubber wherever their properties make it possible, the most important being polystyrene and polyvinyl chloride. These also are long thread-like molecules, built up from styrene and vinyl chloride. Neither of these polymers is really 'rubber-like', but by plasticising them with softening agents excellent electrical insulating materials are obtained to replace rubber in the cable industry.

What will be the result of this development in the post-war period remains to be seen. The qualities of the two products at present appear to be complementary rather than competitive.

# CHAPTER 24
# SCIENTIFIC INSTRUMENTS

*General importance*

The direct economic importance of the scientific instrument industry is not great but its indirect value is very considerable. The manufacture of up-to-date and efficient instruments for conducting industrial investigations of a scientific nature is of the highest importance and the sales of such instruments serve as a barometer to indicate the vigour and progressiveness of the chief manufacturing industries of the country. The necessity of encouraging this key industry has been recognised by the imposition of a 75 per cent *ad valorem* duty on all instruments imported from abroad.

While essentially an industry based on science and research, it is also one in which the greatest skill in craftsmanship is required. An instrument-maker must be a super-mechanic and a craftsman of the highest order: tolerances of a thousandth of an inch are child's play to him. In olden days men of science were their own instrument makers. Newton's investigations were carried out with instruments made by himself; so were those of Robert Hooke and William Herschell; while the names of Davy, Faraday, Dewar, Kelvin and Wheatstone are associated with apparatus of world-wide fame. Today it is different and although there are distinguished scientific men on the directorates of our leading instrument manufacturers, there is no longer the close connexion between experimental scientists in university and research institutions and in instrument making.

In times of emergency the demands for precision instruments of all kinds and for new forms to meet fresh conditions are enormous as was shown during World Wars I and II. The premises and staffs of instrument-makers had to be expanded to meet the national needs, especially of the Fighting Services, and firms were commissioned to undertake, wholly or in part, the manufacture of instruments they had not previously attempted. The shortage of skilled men, due to lack of employment in times of peace, was serious; though the wise planning by the Government in conjunction with industrial firms during the inter-war period for the supply of various types of optical glass should be mentioned with satisfaction.

*Organisation of industry*

The whole question of the organisation of the industry will need careful consideration and steps should be taken to ensure that it is capable

of making first-class instruments in adequate quantities to meet conditions at all times. In any such re-organisation some degree of rationalisation should be considered. Instead of a number of firms competing with each other on a price basis for some relatively small section of production, an understanding between manufacturers might be reached whereby concentration could be brought about and a higher degree of efficiency in each section secured. Progress in this direction has been made in recent years and the Scientific Instrument Manufacturers' Association has been playing an active part in bringing about a better understanding in the matter. It is not suggested that one large corporation should encompass the whole diversified field or even that two or three should do so; but by understanding within the industry, firms might undertake defined sections of production and be of sufficient size to maintain well-staffed and progressive research and development departments such as those which have been in existence in certain leading firms for some time. Some firms at present are largely trading on reputations made years ago and possess so-called scientific departments which are little more than handmaids to production.

In Germany encouragement has been forthcoming from the Government with lavish orders for Service requirements present and future. Such assistance enabled the Jena glass works and the Zeiss optical firm to embark on large scale production with ample facilities; and on this foundation to establish a world-wide export market. Moreover as an integral part of the campaign for export trade, agencies in the countries of purchase were established and customers could be given a local service through which spare parts were supplied and expert repairs effected. A British firm without such local facilities to assist it has not unnaturally suffered in the competition. These considerations apply also to other manufactures but in an industry such as that of scientific instruments they are very important.

*Attitude of other industries*

Another factor is the attitude of industrial manufacturers and users generally towards British scientific instruments. Largely due to the prestige enjoyed in the past by well-advertised foreign instrument makers, the impression is still widely held that British instruments are not good enough to meet modern conditions of use. In fact some of the leading instrument firms find it a good plan to get their instruments used abroad in the first instance and by this means secure the confidence of technicians here. The position is reminiscent of the time when a British musician assumed a foreign name in order to get a hearing from an audience in this country, a practice that is still not unknown. And yet at the end of the 19th century the attitude of industry was very

different, at all events towards the products of mechanical engineering, in which this country led the world. Not only was the country well satisfied with its machine products of all descriptions but it thought it a disgrace to introduce foreign instruments and machinery, or even ideas from abroad. The inferiority complex is of comparatively recent origin and, though far from justified in many directions, is unfortunately widely prevalent. All this needs changing and a feeling of 'winning' created, with justification behind it. Self-complacency needs eradication in quarters where it exists but it is equally important to realise the successful endeavours not only in the distant past but those of today.

*British achievements*

The considerable achievements of the industry are indicated by the examples cited below.

The rapid development of electrical and telegraphic engineering in the middle of the 19th century presented the instrument maker with many problems of measurement. Kelvin, who had long insisted that true physical knowledge could only be based on accurate measurements and that the design of a measuring instrument must be such that its use involved no interference with the quantity to be measured, devoted himself whole-heartedly to the construction of instruments to meet the new requirements, and a series of instruments associated with his name resulted from his efforts. Thus his mirror galvanometer emerged in 1867 to meet the need for a sensitive detector in cable telegraphy and cable testing; the requirement for the accurate measurement of contact potentials brought forth his many electrostatic instruments; and the problem of the measurement of very low resistances found its solution in Kelvin's double bridge. Moreover, Kelvin's zeal for accuracy of measurement led him to construct instruments capable of dealing with every known magnitude of current and voltage. His success in this endeavour is shown in his current balances and in his electrostatic instruments from the Absolute Electrometer to the high tension types of electrostatic voltmeters. Kelvin's interest in instrument design was not confined to the electrical field. His introduction of the logical Absolute Scale of Temperature was followed by the production of his constant-pressure gas thermometer in 1880 and his steam-pressure thermometer of about the same date. His study of the magnetic and dynamic requirements of navigational compasses led to his famous dry-card compass which instilled new life into the compass-maker's art. Kelvin's instruments achieved a world-wide fame and it is small wonder that the reputation of British instruments has never been higher than in the period immediately following his era.

The safety and maintenance requirements of electrical installations,

and of house-lighting, created a demand for a ready instrumental means of testing insulation. Through all the development of electrical engineering this demand has been continuously met by British developments. In 1882 Professor Ayrton designed an ohmmeter which embodied electromagnetic principles and the readings of which were independent of the voltage of the activating battery. Evershed saw in this instrument the solution of the problem of insulation testing, and from 1889 onwards devoted his attention to the conversion of Ayrton's instrument into a form of greater practicability and portability. From that time until the present, continuous developments and modifications to meet new and more stringent requirements have taken place, and today the 'Megger' instruments, with their self-contained high-tension generators giving a smooth and constant voltage under hand-operation and with their freedom from error due to the earth's and other external magnetic fields, are capable of measuring resistances from 20,000 million ohms to a small fraction of an ohm, and are in use under all conditions throughout the world.

Duddell's invention of the oscillograph and its subsequent development by the Cambridge Instrument Company enabled a detailed study to be made of the nature of electrical oscillations, and the knowledge thus obtained profoundly affected the design of high-tension generators, switch-gear, etc. The low inertia of the Duddell oscillograph represented a triumph of design and gave to the instrument a wide field of application both in academic and industrial research. An inertialess system was later provided by the cathode-ray oscillograph and the contributions to the development of this instrument by British workers were outstanding. The experience gained in this field was of the greatest value in the development of television in which notable advances were made in this country in the years immediately preceding World War II.

Nothing is more vital in industrial processes than the measurement of temperature and in this field every scientific principle has found its counterpart in a type of instrument. The famous bridge of Professor Callendar, and later modifications of it, used in conjunction with a platinum resistance thermometer is capable of detecting changes of temperature of less than $\frac{1}{100}$th of a degree; the thermo-electric pyrometer and the more robust types of resistance thermometers allow the high temperatures employed in many industrial processes to be recorded and controlled; the mercury-in-steel thermometer permits of temperature measurements at long distances; and optical and radiation pyrometers enable the temperatures of furnaces and of molten metals to be obtained with accuracy. British research and development have contributed largely to the highly specialised uses of pyrometry made in industry today, and have greatly influenced the design of modern instruments.

From the time of Newton onwards, British craftsmen have played a

notable part in the production and development of optical instruments, and at least two firms founded in or before his day are still in existence. For a long period the requirements for optical instruments were largely met by this country. Thus the equipment of astronomical observatories, which sprang up with the growth of modern astronomy, included instruments supplied by such firms as T. Cooke & Sons and later Sir Howard Grubb Parsons & Co. In 1870 the former firm completed an order for the 'largest telescope in the world', which had an object-glass of 25 inches diameter and which can still be seen at Cambridge. In photography Ross, Dallmeyer, and Taylor Taylor & Hobson are associated with camera lenses of the highest quality. To Dennis Taylor belongs the honour of inventing the 'Cooke 3-lens photographic anastigmat' the forerunner and parent of most types of camera lenses in general use today; see also p. 125.

A knowledge of the minute structure of the worked and lapped surfaces of metal components is of vital interest to the engineer concerned with the life, efficiency and general performance of many mechanical systems. The high performance of present-day aero-engines could not have been achieved without great attention being given to the quality of the surface finish of the moving components. Messrs. Taylor Taylor & Hobson have in recent years developed an instrument in which the movements of a stylus as it passes over a surface are, by an electrical linkage system, recorded in graphic and highly magnified form. By means of this instrument a picture of the contours of an apparently mirror-like steel surface can be obtained, and the instrument provides a useful tool for use in investigations into the form of surface undulations which are deleterious or otherwise to performance.

In the evolution of the modern theodolite with its almost uncanny accuracy much inventiveness has been displayed by British workers. This has been especially evident in the devising of ingenious methods for the elimination of all instrumental errors. A notable contribution in recent years has been the development of methods by means of which calibrated master-circles on glass may be quickly duplicated without appreciable loss of accuracy.

The knowledge of the nature of the atom, which has resulted from investigations of spectra and the accurate measurement of the wavelengths of spectral lines, owes much to wavelength spectrometers designed and produced by Adam Hilger. It is safe to say that these instruments are without equal in the world and form a part of the equipment of most modern laboratories engaged in spectral analysis. The performance of these instruments has been a great stimulus to the progress of spectro-chemical analysis in industry which allows the composition of materials to be determined easily and quickly and thus furnishes an

effective means of 'quality control'. Another notable achievement of this firm has been the conversion of the abstruse phenomenon of interference to practical use by evolving absolute standards of length in which the unit of length is the wavelength of light, and in producing interferometers in the form of workshop tools by means of which the performance of optical components and instruments can be assessed absolutely and quantitatively rather than qualitatively by visual estimation.

It is not surprising that a maritime country should have paid particular attention to marine instruments and that British marine instruments should be found installed in the merchant navies of the world. Particular mention may well be made of one instrument, the echo-sounder, which provides a means of plotting the contours of the sea bed and has added greatly to the safety of sea traffic. This instrument operates by measuring the passage of time taken by sound to travel from a ship's bottom to the sea bed and back again, and is a good illustration of the incorporation of scientific laws and principles, long considered to be mainly of academic interest, in an instrument of great utility and public benefit. The echo-sounder employing waves of audible frequency furnishes one of the rare instances of the practical application of the knowledge of sound phenomena, whilst the super-sonic echo-sounder, in which inaudible sound waves of much higher frequency are employed, shows that even an obscure phenomenon, such as that of magnetostriction, may be successfully utilised. Incidentally the development of these instruments indicates the good results which may be obtained by close co-operation between a scientific department of the Services and a commercial firm; see also p. 229.

This country is justly proud of its Navy and of the efficiency with which it carries out its numerous and varied tasks. World Wars I and II have demonstrated in a practical manner that the safety of these islands is ultimately dependent upon naval power. Steel and guns would, however, be of little avail without vision, and the eyes of the Navy are found in its optical instruments and, in particular, in its range-finders. It is therefore fair to say that every naval success of the two wars has provided a tribute to modern British optical instruments. More than one British firm has contributed to the evolution of the Coincidence Rangefinder, but for many years past the name of Barr & Stroud has been indissolubly linked with range-finders of the highest performance. The conditions of modern warfare are such that the use of anything of less than the highest quality may well lead to disaster, and it is satisfactory to realise that all the complicated and arduous ranging requirements involved in the use of guns from those of the field artillery to the mammoth weapons of the battleship have been successfully and adequately met by British development and enterprise.

*Co-operative research*

A considerable source of strength was added to the industry by the formation of the British Scientific Instrument Research Association in 1918. From that date manufacturers have been able to turn to a central agency where their scientific problems could be examined and help accorded. Especially useful to the less well-equipped firms, the Association has been of great assistance to all its members. During World War II, when Government contracts had to be widely placed, the membership more than doubled, since non-member firms found that without the assistance of the Association fulfilment of their contracts was difficult, if not impossible.

Two sections of work may be mentioned as showing the value of the organisation to manufacturers. The question of abrasion and polishing —of great importance to the makers of lenses—was examined with care, and as a result of research a quick abrasive and a polishing powder (known respectively as Sira Abrasive and Sira Rouge) were devised and arrangements made for their commercial production. The saving in labour in the preparation of optical lenses has been great and the preparations have also proved of considerable use in the lapping and polishing of metals.

Before World War I, the making of 'graticules' for optical instruments was almost entirely a German monopoly. The Association devised methods of more than one kind for their production by British firms who were placed in a position to make graticules for themselves. Not only so, but during World War II when the United States were in difficulties the members of the Association placed the whole of the results of many years' research work on the subject at the free disposal of our ally and its manufacturers.

The Association is also of added value to the Fighting Services, since they have free access to all the results of the Association and keep in close touch with its work. They find these contacts of much use, both in peace and war, and are able to get readily scientific and technical advice on special subjects. Because of the Service interest, and the key nature of the industry, the Association receives from D.S.I.R. special terms of grant-aid.

But the Association was never properly representative of the industry until the outbreak of World War II, and has not been operating on an adequate footing. It is greatly to be hoped that after the war a radical change will be made in the size of the Association. New and more suitable premises are in prospect (see Appendix IV). The size of its co-operative research organisation should not be governed by the dimensions of the industry but by its responsibility for the well-being of the scientific work of all British manufacture. It is the duty of industry and of the State to see to this.

# CHAPTER 25
# SHIPBUILDING

### *Historical*

To an island people, shipping is a primary concern and the possession of a flourishing shipbuilding industry is essential. King Alfred was its founder in this country. Under his direct tutelage long ships with 60 oars were built to repel the Vikings. It was not, however, till the reign of Henry VIII that a national navy was created and national pride in it engendered. Henry built royal dockyards at Woolwich and Deptford and founded Trinity House in 1514 by Charter, for 'the relief, increase and augmentation of the shipping of this Realm of England'.

### *Wood to iron*

In the early years of the 19th century, the transition from wood to iron for ship construction gradually took place. In 1844 the number of iron ships on Lloyd's Register was seven steamers and eleven sailing ships out of a total of 12,000 ships, but their size was very small at that date. The average tonnage of steamers built in that year was 130 tons. Even by 1860 the greater part of the mercantile marine was of wood, though the future possibilities were indicated by the building of the famous screw and paddle steamer *Great Eastern* in 1857. In this early transition stage a combination of wood and iron was employed, the internal structure being of iron with wood planking attached to iron ribs forming the outer skin. This 'composite' structure was the basis on which some of the famous 'clippers' of the 1860's were built. With the opening of the Suez Canal, the clippers became uneconomic as compared with steamships. They could not sail through it.

### *Iron to steel*

A great impetus was given to metal construction by the development of mild steel in the middle of the 19th century. The first steel steamer was classed with Lloyd's Register in 1864, but it was not until fifteen years later that improvements in manufacture enabled a reliable material to be produced at a price rendering its use generally possible. The reduction in scantlings due to the superior qualities of steel compared with iron was an important factor in hastening the change-over and in little more than ten years from its adoption, mild steel had practically superseded iron and still holds the field. The development of steam ton-

nage followed the progress made in steel production, and was especially influenced by the introduction of the Siemens-Martin open-hearth process (see p. 92), whereby a mild and ductile steel became available, superior to iron and cheaper than steel made by the Bessemer process of that time. The open-hearth steel with a tensile strength of 30 tons per square inch compared with 22 tons per square inch for iron also permitted a substantial reduction in the scantlings of marine boilers with an increase in steam pressure, to meet the needs of the engineer for the development of the multiple expansion reciprocating steam-engine.

*Engine development*

Towards the end of the 19th century the marine reciprocating steam-engine reached its zenith, in size and horsepower, when luxury Atlantic liners were introduced. One of the best-known was the *Kaiser Wilhelm II*, a 19,360-ton liner built in 1902 with quadruple expansion engines of 43,000 horsepower, a boiler pressure of 225 lb. per square inch and a speed of 23½ knots. In water-tube boilers also much higher steam pressures could be obtained. France made greater headway in this direction than Great Britain with the Belleville boiler. In 1889, twenty such boilers with a steam pressure of 240 lbs. per square inch, were fitted in the Messageries Maritimes steamer, the *Australien*. Other developments in the 1880's were the use of oil fuel and the introduction, by James Howden, of mechanical forced draught applied to the multi-tubular marine boiler. The first forced-draught installation with air pre-heating was fitted in the *New York City* in 1884. The progress of oil burning was slow, chiefly due to the difficulties of atomising the oil, but an oil-burning system was installed in the *Gretzia* in 1881.

In 1897 came the great challenge to the reciprocating steam-engine which by that date had reached its peak of development with powers exceeding 30,000 horsepower. In that year at Spithead, Sir Charles Parsons, with his *Turbinia*, outpaced the speediest vessels afloat, for, by means of the turbine, his experimental vessel attained a speed of 34 knots compared with the 27 knots of the latest form of torpedo boat in the British Navy. The story of Parsons' turbine cannot be told in full here, but it probably represents the outstanding achievement in British engineering science and the supreme example of confidence in a scientific discovery. Reference is made in the account of the electrical industry (p. 40) to the effect of the turbine on electrical generation but the shipbuilding industry owes to Parsons an equal debt. His courage in the face of initial difficulties was not the least of his high qualities. The *Mauretania* and *Lusitania*, built in the first decade of the present century, are examples of fast Atlantic liners driven by steam turbine engines: the former held the Atlantic blue riband for 22 years. As an

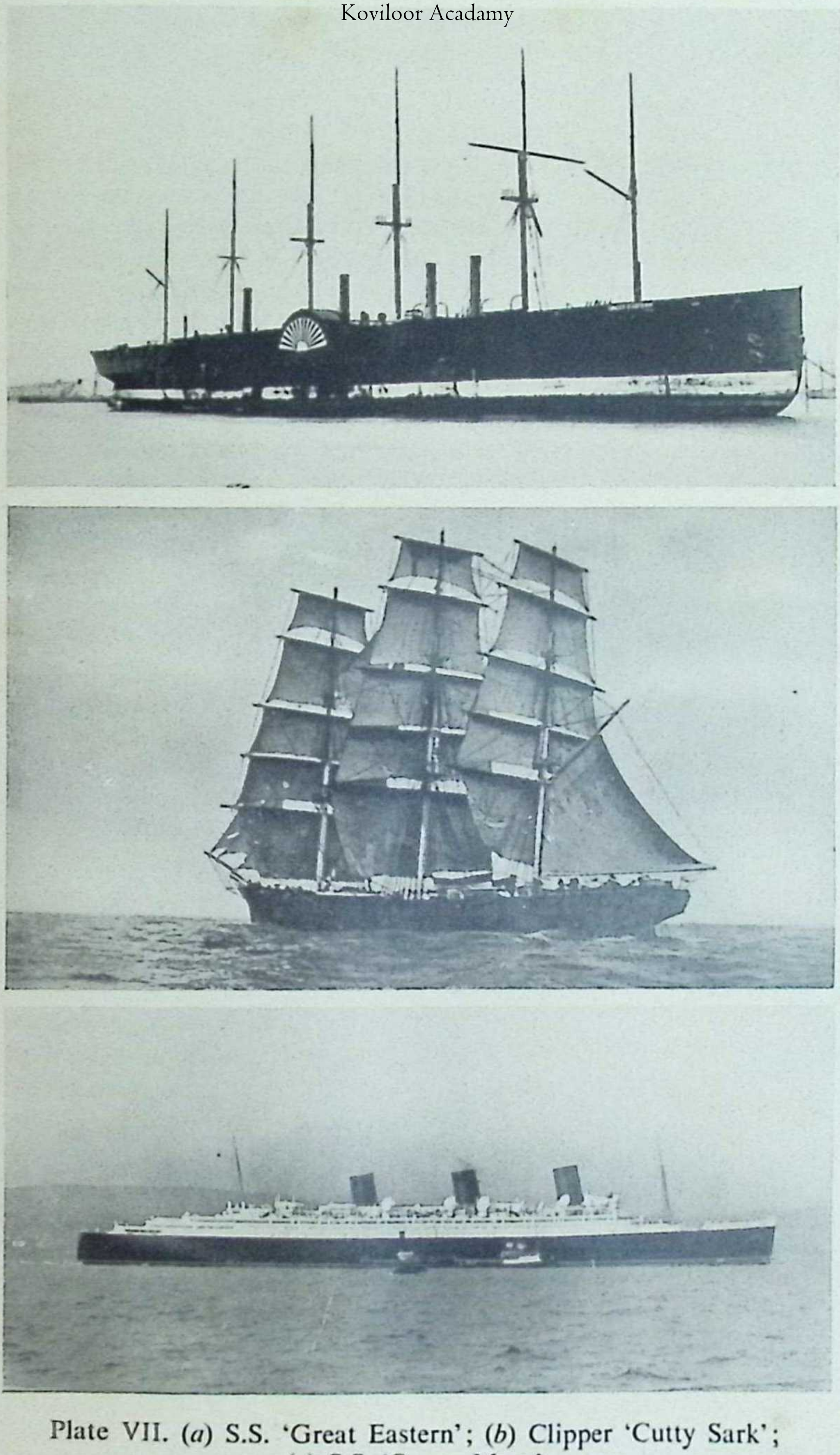


Plate VII. (*a*) S.S. 'Great Eastern'; (*b*) Clipper 'Cutty Sark'; (*c*) S.S. 'Queen Mary'.

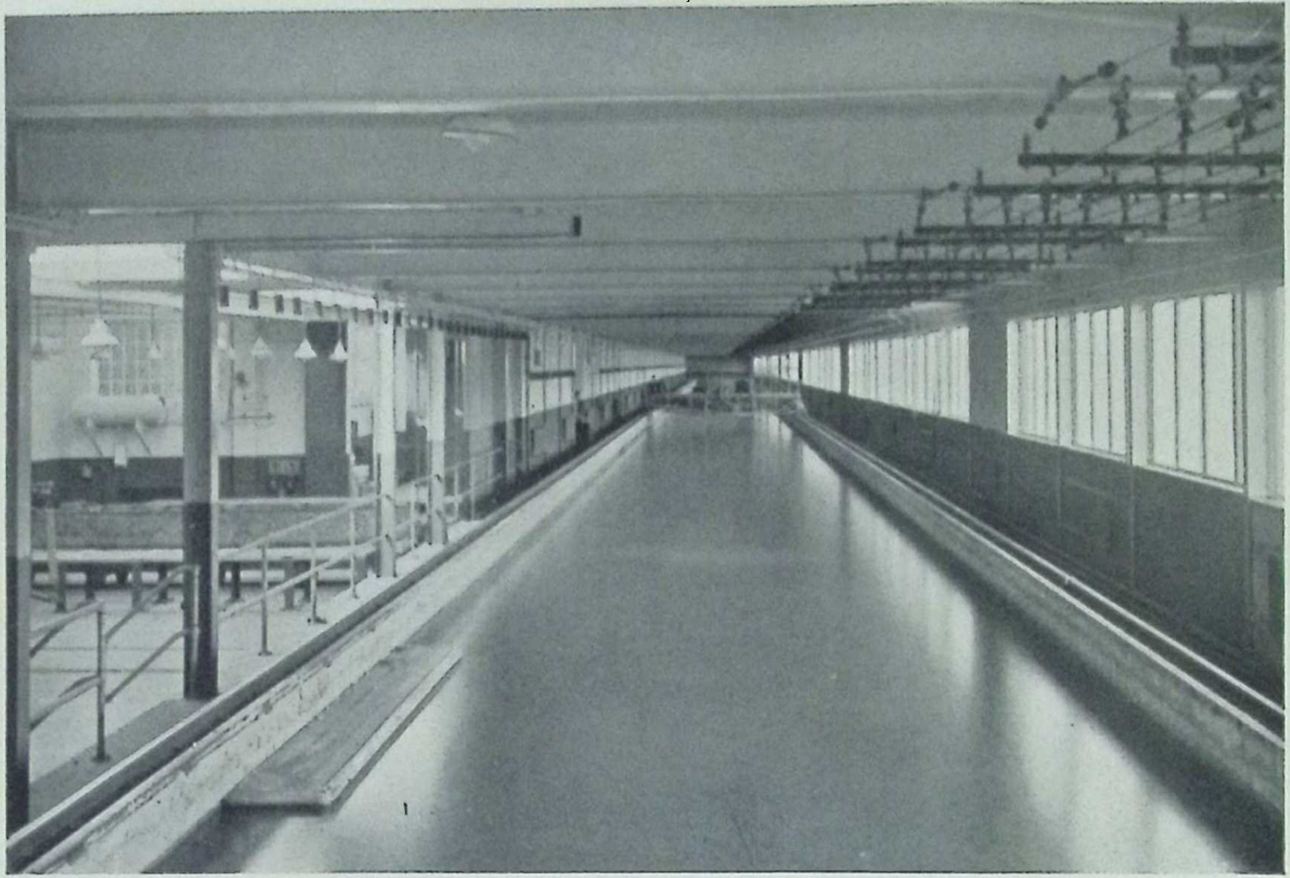


Plate VIII. Tank at the National Physical Laboratory.

indication of the increasing use of steam turbines at this period, it may be noted that in 1905 there was a gross turbine-driven tonnage of 16,000 on Lloyd's Register; by 1908 it had increased to 166,000 tons. The Admiralty, after 1903, adopted the turbine in naval ships and the *Dreadnought* was the first battleship to be so equipped.

The supremacy of steam for marine propulsion was seriously challenged about 1910 when the first sea-going vessels were fitted with heavy oil engines. Since that date the oil engine has made such rapid strides that over 60 per cent of new construction is now fitted with this type of machinery. The increase in the use of the internal combustion engine for marine propulsion was rapid, for the economy in fuel consumption and the saving of labour in the stoke-hold was clear. The earliest sea-going vessel, other than small craft, to be fitted with heavy oil engines was an Italian twin screw ship built at Ancona in 1910, the engine being built in Switzerland. In the same year, the motor-ship *Vulcanus* was built at Amsterdam. In 1912 the well-known motor-ship *Jutlandia* was built in Great Britain and, in 1914, a two-stroke opposed cylinder engine was evolved in Sunderland, the outstanding oil engine developed in this country.

The vast expansion of oil fuel in all branches of engineering made the question of its conveyance in bulk of major importance. In recent years, about 20 per cent of the total construction in British yards has consisted of tankers.

The first passenger liner to be built with turbo-electric machinery was the *Viceroy of India* in 1929. From that date further mammoth liners have been constructed, culminating in the plain turbine-driven *Queen Mary* and *Queen Elizabeth*; the last-named being capable of over 28 knots with a gross tonnage of 85,000.

### *Welded ships*

One of the most recent developments in shipbuilding has been the increased use of welding in place of rivetting. Though welding has been used for over 30 years to a limited extent for repair work, it was not until 1920 that the first all-welded ship (*Fullagar*) was built in this country. But the subsequent progress was not rapid until recently, when a great impetus was given by World War II to speedy construction to replace losses. The process greatly facilitated pre-fabrication and mass production. Further reference to welding will be found on p. 104.

### *Ship design*

During the long history of shipbuilding, one of the vexed questions has been the form of hull offering least resistance to propulsion, and

much research work on the subject has been done. The pioneer work on ship models was conducted by William Froude about 1870 and the first experimental tank for testing models was built for the use of the Admiralty. The National Physical Laboratory now has two tanks available for investigations of designs by shipbuilding firms, several of which have tanks of their own. Wax models are made on the basis of the design proposed and these are tested in the tank under scientific control and experiment so that improvement may be suggested. Propeller design is similarly investigated. During the last twenty years, increase in our knowledge of hull-form resistance has brought about a reduction of 8 per cent in the resistance of the average merchant cargo ship. Over the same period, experimental tank research has added to the knowledge of the designer in the selection of the best propeller dimensions, blade shape, etc. to suit ship, speed and engine conditions. This has resulted in a general gain of 9 per cent in propulsion efficiency, so that 17 per cent less fuel is now burned to produce the same speed—due to improved design of the hull-form and propeller.

*Co-operative research*

The industry owes much to the Institution of Naval Architects, formed in 1861, which provides a forum for the presentation of papers and the free discussion of new ideas and theories. Similar institutions now exist in all the principal shipbuilding districts and their influence on the structural design of ships has been greatly beneficial. The latest source of scientific and technical assistance is the British Shipbuilding Research Association formed in 1944, largely financed by the Shipbuilding Conference.

*Output*

Shipbuilding is perhaps the greatest assembling industry in the country. Many other trades depend directly or indirectly upon it so that when the demand for new tonnage falls off, depression spreads far beyond the shipbuilding centres. The outstanding feature of British shipbuilding is the sea-worthiness of the vessels built, for safety of life at sea has been its first requirement. The reputation of British shipbuilders abroad has been great and not very long ago more than 50 per cent. of the world's merchant tonnage was built in this country. The fluctuations that have occurred in the output of mercantile ships have been considerable as the following table from 1905 indicates; the similar figures of output from abroad are included for comparison.

GROSS TONNAGE LAUNCHED

| | *Great Britain and Ireland* | *Abroad* |
|---|---|---|
| 1905 | 1,623,168 | 891,754 |
| 1910 | 1,143,169 | 814,684 |
| 1913 | 1,932,153 | 1,400,729 |
| 1920 | 2,055,624 | 3,806,042 |
| 1926 | 639,568 | 1,035,409 |
| 1931 | 502,487 | 1,114,628 |
| 1938 | 1,030,375 | 2,003,218 |

Figures are not available since 1939, during which period great expansion in ship construction occurred in this country and abroad, especially in the U.S.A.

# CHAPTER 26

# TEXTILE INDUSTRIES

## COTTON

*Historical*

Cotton goods made from raw cotton imported from various parts of the world have in the past been the backbone of the British export trade. The chief cotton crop is that of the United States, grown in the Mississippi valley, Texas, and the Carolinas. 'Sea Island' (mostly from the West Indies), Egyptian and Indian cottons are the other main types imported. These cottons vary in length of staple and consequently in their value from a processing point of view. 'Sea Island' cotton has the longest staple, followed by Egyptian, American and Indian in that order.

The industry has been carried on since the 17th century in Lancashire and northern Cheshire where the prevailing atmospheric conditions provide the appropriate degree of humidity. But it was not till the 18th century and the introduction first of water and then of steam power that the industry grew to important dimensions. The steam engine was first used for driving cotton machinery in 1785.

British inventors contributed largely to the development of the industry. Sir Richard Arkwright, 'the founder of the English cotton industry' and the man chiefly responsible for introducing the factory system into this country, patented his spinning frame in 1769; at an earlier date (1733) John Kay invented the flying shuttle; James Hargreaves the spinning jenny in 1764; Samuel Crompton the spinning mule in 1779; while a number of other, though less outstanding, British inventions were made in the same period. A Frenchman, Joseph Jacquard, revolutionised the weaving machinery by the introduction of his loom at the beginning of the 19th century. These inventions and the use of steam as the motive power quickly replaced most of the handicraft on which the industry had depended and led to a very large export trade. They also gave rise to the separate development of the spinning from the weaving section of the industry. The subsequent processes of bleaching and dyeing—the so-called 'finishing' end of the trade—called for new methods of approach and development and have also remained distinct. Thus it is that the cotton industry, like the other textile industries, has been for the most part organised horizontally. A vertical organisation of a cotton firm, i.e. one dealing with all sections of manufacture from the raw product to the finished article is rare in this country.

### *Co-operative research*

The British Cotton Industry Research Association, formed in 1920, has made a number of improvements in the processing of cotton goods but perhaps one of its most important roles has been to bring together the several sections of this horizontally organised industry so that the inter-relationship of the processes can be studied. Long range research, starting with the constitution and inherent properties of the cotton fibre, has been a constant aim of the Association and its initial years were largely devoted to it, so that subsequent investigations might have a sure ground on which to make new advances. Research of this kind by individual firms has not been a prominent feature of the industry. The spinning and weaving firms, comprising a thousand or more manufacturing units, perform a comparatively simple and purely mechanical process. The same method is employed in every spinning mill and almost the same in every weaving shed. These firms have found no purpose served by establishing research and development departments. They look to the Research Association with its headquarters at the Shirley Institute as the source of further scientific and technical progress.

The case is different with firms engaged in the finishing end of the trade and particularly with the few firms which are vertically organised. One such firm has for many years organised and maintained an extensive research department and its crease-resisting fabric is one of the results. Research extending over many years was necessary before a way of impregnating the cotton fibre with a plastic material to give it resilience was found.

### *Cotton Industry Act*

Since 1940 a levy has been made on the industry under the provisions of the Cotton Industry Act. This levy is made for the support of the Cotton Board and the objects for which it was established. One of these objects is research and the funds specified in the Act can be used by the Cotton Board in support of research work conducted at any suitable centre. In practice the Board makes these funds available to the Research Association, though continuance of the subvention is dependent on the Board being satisfied with the results.

The Cotton Board has recently made a report (Report of the Cotton Board Committee to enquire into post-war problems, January 1944), to the Board of Trade. In the report reference is made to the need for scientific research for the industry and tribute is paid to the work of the Research Association, but it gives the impression of representing the greatest common measure of the opinions of a number of competing interests. Its keynote like that of the Cotton Industry (Reorganisation)

Act, 1939, which was put into cold storage on the outbreak of World War II and replaced by the Act of 1940, is price control at each successive stage of production. The report assumes as axiomatic the horizontal organisation of the industry and points out that four or five prices are quoted at the different stages of production and must be accepted before an overseas order for the finished goods can be booked. To give assurance to the different sections, it is contended that minimum prices should be laid down at these successive stages and controlled by a central body acting under legislative powers. Many factors other than research have, no doubt, to be taken into account, but the report hardly indicates much attempt to melt the frost of tradition, or to point a way to producing a better article than its overseas competitors at a comparable price. The Government in its review of this report appears to take the view that price control is not likely to furnish a sovereign remedy for the troubles of the industry and that greater importance needs to be attached to reorganisation from spinning to merchanting and to technical equipment. In the latter connexion it is remarkable that 95 per cent of the weaving looms in the U.S.A. are automatic, against only 5 per cent in this country. As cotton-growing countries devote further attention to the manufacture of cotton goods, the Lancashire industry is likely to lose still more of its export trade in cheap goods. The exports of 1939 were about 50 million pounds sterling compared with about 80 million sterling in 1903. Increasing attention will have to be paid to the finer qualities, the higher class goods derived from long staple cotton. And for their production intensified research will be called for.

The industry may well develop also in new directions by producing, on a cotton basis, fabrics previously derived from other vegetable fibres. During World War II a number of fabrics previously made from flax have been produced in cotton with success.

*Machinery research*

The Research Association in recent years has largely developed the engineering and machinery side of its programme and has established extensive plant on which fairly large-scale experiments on new types of cotton goods can be tried out, and preliminary laboratory results tested under commercial or semi-commercial conditions. The attention given to machinery and engineering enables work to be done on improvements in existing textile machinery in collaboration with, or in addition to, the textile machinery firms. One of the achievements of the Association has been the 'lint recoverer', a machine for cleaning the short waste material having a large admixture of dirt of all kinds. The machine utilises a stream-lined airflow which carries the good lint forward but

allows the heavier trash to fall out. In this way material previously discarded as worthless has been made serviceable.

The expenditure of the Association in 1939 was about £80,000 on cotton research alone, but this is an estimate since the Shirley Institute also conducts investigations in a special department for the silk industry. In its rayon department problems of processing are dealt with; but it does not deal with the production of the rayon fibre.

### *Export figures*

As indication of the rise and fall of cotton-manufactured exports, the following approximate figures are interesting:—

U.K. EXPORTS OF COTTON YARNS AND MANUFACTURES

*Million £'s*

| | | | | | |
|---|---|---|---|---|---|
| *1821* | 16·1 | *1891* | 63·9 | *1930* | 88·2 |
| *1831* | 17·3 | *1901* | 68·3 | *1931* | 57·0 |
| *1841* | 23·5 | *1911* | 108·7 | *1932* | 63·3 |
| *1851* | 30·1 | *1920* | 379·4 | *1933* | 59·4 |
| *1861* | 46·9 | *1921* | 170·3 | *1934* | 59·0 |
| *1871* | 72·8 | *1924* | 200·4 | *1939* | 49·0 |
| *1881* | 79·1 | *1929* | 136·3 | | |

## LINEN

### *Historical*

The earliest known examples of woven fabrics were made from flax, specimens of fine linen having been found in early Egyptian tombs (*circa* 5000 B.C.). The strength of the flax, which is about three or four times that of the cotton fibre, was early recognised and for fineness combined with strength flax has no equal among the vegetable fibres. But with the advent of the inventions in the 18th century for cotton manufacture, the use of flax, which was widespread over Europe partly in the production of lace, began to diminish. Hand-weaving, which had been the practice, could not compete in quantity of output, so the machinery invented for cotton goods was adapted for linen manufacture and, with necessary modifications, became the general practice in the 19th century. There are, however, sundry preparatory processes to which the flax plant has to be subjected in order to obtain the necessary yarn. 'Retting', the process of steeping the flax in water to loosen the fibre from the surrounding plant tissues, and 'scutching', by which the fibre is set free from the woody part of the stem, are the two most important.

*Sources of flax*

Before World War I the finest flax was obtained from Belgium and about $\frac{5}{6}$ths of the imports of flax came from Russia. When the leading manufacturers centred in Northern Ireland, and Scotland, decided to form a co-operative Research Association in 1917 (the Linen Industry Research Association), they were conscious of the difficulties they were experiencing through the cutting off of continental supplies of flax, and were concerned to put the home flax growing industry on a sounder basis, and to extend its cultivation in the Empire. They considered that the production of pedigree strains which could be cultivated in the United Kingdom or the Empire was likely in the long run to be of more importance than the improvement of the manufacturing processes. In this project the newly formed Research Association was singularly successful and strains have been cultivated which give a much higher yield of flax as well as a better quality. The attitude is interesting, for linen manufacturers, like those of wool, have taken part in what was an agricultural quest.

*Processing*

More recently the manufacturers have further fostered flax production by subsidising research on the methods of separation of fibre from flax straw by retting and scutching, with the object of placing these operations on a factory basis, including the recovery of flax seed for sowing and feeding purposes. The production of 'green' or 'natural' flax has also been undertaken, accompanied by the recovery of the seed; and in this endeavour the Research Association has also played an active part. The object is to avoid retting and to produce a yarn without subjecting the straw to this steeping process. Such success has been achieved, especially for the coarser counts, that this flax is specified for the production of airmen's parachute harness; but for the finer counts it seems doubtful whether the omission of retting is feasible as the fibre does not come out so clean. If the new factories, whether only for flax scutching or for retting in concrete tanks as well, coupled with processes for deseeding and drying, prove to be a commercial success in peacetime, the supply of yarn from British sources would place the industry in a position it has not hitherto enjoyed, and this is the general aim of the manufacturers and of the Government of Northern Ireland which naturally takes great interest in this very important source of prosperity to Ulster.

The industry is of much smaller dimensions than those of cotton or wool, and although it includes a number of large vertical units it is in the main organised horizontally like cotton and wool.

*Export figures*

The export figures for linen yarn and finished products at typical periods are as follows:

1905—£6,078,820.
1913—£7,897,556.
1918—£8,795,614 (Price factor 2·224 times that of 1913).
1920—£20,443,656 (Price factor 4·715 times that of 1913).
1937—£7,789,000.

*Research in the industry*

Manufacturers in their own laboratories have devised improved methods of chemical retting to hasten the steeping process as well as improvements in bleaching technique; while the textile machinery makers and private inventors have made new types of machine with a view to improving the rate of production or the reduction of waste. Thus for 'hackling' machines, differential sheet speeds, and automatic ending and spreading devices have been introduced. Drying machines for flax straw among other improvements have also been made.

The strength of the flax fibre and the fineness to which it can be spun, especially by wet spinning as used for the finest material, give it a high value and make possible the production of a textile which cannot be equalled in certain respects by any other fibre. The linen thread from which some of the Belgian laces are made is spun by hand from extremely fine filaments. Owing to the fine nature of the fibre, it lends itself to admixture with rayon, and 'union' fabrics are likely to form an important product in the future.

## RAYON

*Early years*

In 1883 Chardonnet invented a way to make a thread by forcing nitro-cellulose through a fine orifice. That discovery laid the foundations of a new industry which has already become one of considerable magnitude and is likely to grow still larger.

*Processing*

The rayon filaments made from cellulose or cellulose derivatives are prepared by processes that have the common feature that the cellulose is first converted to a soluble substance, the viscous solution of which is extruded through fine holes to form the filaments made by removing the solvent from the syrupy jets. The filaments are then suitably purified and packaged.

Three processes are employed in industry for effecting this change:

(i) *The viscose process*. Purified *wood* cellulose is treated with a suitable mixture of carbon disulphide, caustic soda and water to form sodium cellulose xanthate which is extruded through fine orifices into an aqueous solution of sulphuric acid to form filaments of *regenerated cellulose*. About 66 per cent of the world production is made by this process.

(ii) *The acetate process*. Purified *cotton* cellulose is converted by means of acetic anhydride and acetic acid to a cellulose acetate having about 7 out of 9 of its hydroxyl groups acetylated. This acetate is dissolved in acetone and the solution is extruded into warm air to form filaments of *cellulose acetate*. About 28 per cent of the world production is made by this process.

(iii) *The cuprammonium process*. Purified *cotton* cellulose is dissolved in a suitable solution of cuprammonium hydroxide which is extruded into aqueous caustic soda to form filaments of *regenerated cellulose*. About 4 per cent of the world production is made by this process.

The processes by which rayon is made have been so greatly developed in recent years, that by 1937 the world production of rayon was more than fifteen times that of real silk. The industry is yet in its infancy and there is little doubt that by means of research further improvements in existing and the production of new fibres will be obtained. The industry based as it is on scientific discoveries looks for help to science much more than the older textile industries, especially on the production side, and the great firms have large and highly efficient research and development departments. The production of rayon as a raw material corresponds to the growing of raw cotton; and much research is conducted on cotton breeding overseas. But the science involved in rayon production is in a different field and lends itself to laboratory work in this country. Research on the processing of rayon is probably less than that on cotton.

*Co-operative research*

So far as the processing of the fibre into textile fabrics is concerned, the firms have made much use hitherto of the British Cotton Industry Research Association, and at the Shirley Institute there is a strong rayon department largely supported by contributions from the rayon firms. The expenditure of this department in 1939 was about £9,000, and it is well equipped to deal with the problems involved. The methods employed are similar to those of the cotton and silk industries. The continuous filament processing and the weaving are of the silk type and the staple-fibre spinning resembles cotton spinning, for the staple can be cut to suit cotton machinery. It can also be cut to suit woollen and worsted machinery.

There is at present no separate co-operative Research Association for rayon and as already explained only processing research is conducted at the Shirley Institute. The possible formation of a Rayon Research Association is under consideration and there are a number of factors to be taken into account. First there is a very pronounced feeling, voiced emphatically by prominent leaders in the trade, that this young and flourishing industry must not be trammeled by too close an association with the traditional practices of cotton processing. It must be free to develop and not be tied by procedures which may be necessary for an old-established industry. The rayon industry defies the accumulated prejudices and traditions of the past. While therefore the rayon firms have received and acknowledged great help on the processing side from the Shirley Institute, they remember that it is the British Cotton Industry Research Association with a rayon department.

These are natural and cogent arguments against the present close association with cotton, but they do not seem to provide a conclusive answer to the future needs of research for the industry on a co-operative basis. The extensive equipment required is available at the Shirley Institute and it would seem improvident to duplicate it elsewhere. It is also highly desirable, from all scientific and technical considerations, that research on rayon should be carried out in the closest contact with that on fibres nearly related to it. On the production side there are different considerations to take into account. The firms are likely to wish to retain exclusive knowledge of any new fibres their scientific departments may discover.

When an industry is largely centred in a single firm or combine, or even in a few large units, the prospects of a co-operative Research Association are not bright, as experience has shown. The Portland Cement Research Association petered out for that reason and so did the Photographic Research Association. The Rubber Manufacturers' Research Association very nearly suffered a like fate at one stage of its career. The question calls for full consideration by the industry, taking all the factors into account. Apart from the use of rayon by itself, it is used in 'union' fabrics interwoven with cotton, wool or linen and this side of the industry is likely to continue to form an important part of it, combining as it does the inherent qualities of the two kinds of fibre.

*Production figures*

The following figures of rayon production since 1920 indicate its rapid growth in this country.

U.K. PRODUCTION OF RAYON

| | *Million lb. weight* |
|---|---|
| *1922* | 15·4 |
| *1925* | 26·4 |
| *1930* | 48·8 |
| *1935* | 121·6 |
| *1939* | 180·0 |
| *1942* | 135·0 |

A more recent product is 'nylon', an American invention. Further reference to nylon will be found under plastics (chap. 18), but in so far as rayon is taken to include all man-made fibres it is mentioned here, for it is increasingly being used for garment making. Other new fibres, referred to under plastics, are similarly being exploited.

## SILK

### *Historical*

The manufacture of silk originated in China where it was woven from the fibre from the silk cocoon several centuries before the Christian era. Silk manufacture was introduced into this country in the reign of Henry VI but it was not until the 16th century that persecution of silk weavers on the continent drove them to England to set on foot a flourishing industry here.

The industry is a declining one except for the production of very high-class fabrics, and of superfine silk stockings. High quality 'spun' silk is as expensive as continuous filament and makes a beautiful article. The starting product is cheaper but more processing is involved. Some of the great rayon firms have real silk sections of manufacture, but rayon is a cheaper substitute and is replacing silk to an increasing extent. At the same time rayon has probably replaced cotton and wool products to a greater extent than silk.

### *Processing*

The manufacture of silk fabric is not very different from that of other fibres though its weaving is more exacting. The fibre is spun by the insect and a continuous filament up to 600–800 yards in length can be reeled from a single cocoon. The shorter, waste material is used for less fine purposes by processes similar to those employed in other textile manufacture. The reeled filament goes through a series of processes known as 'throwing', which consists of winding, twisting and doubling so that a stronger and more workable yarn is produced. Subsequent processes consist of scouring or degumming, weighting by the

addition of metallic salts; and dyeing. The same treatment is applied also to the 'spun' silk obtained from the shorter and less fine filaments.

*Co-operative research*

While a great deal of research work has been devoted to the production and utilisation of rayon, that on real silk has been less extensive. A Silk Research Association was formed in 1921 and was established in the University of Leeds but it never became a thriving organisation. One reason was that a university is not the best place for industrial co-operative research. A great deal of most valuable work can be done at universities for an industry, especially on some of the long-range problems, but a university should not be the sole centre of industrial scientific endeavour.

In 1936 the silk industry joined hands with the British Cotton Industry Research Association at the Shirley Institute and arrangements were made by which its special interests were studied side by side with somewhat similar and related problems in the utilisation of cotton and rayon fibres. This was an advantage to both sides. There is no doubt that the interests of silk have been better served under the special committee of supervision drawn mainly from silk manufacturers. The expenditure on 'real silk' research at the Shirley Institute in 1939 was about £4000.

*Exports*

The export figures for silk and silk manufactures for typical periods are approximately as follows:

| | *Million £'s* | | *Million £'s* |
|---|---|---|---|
| *1861* | 1·4 | *1920* | 5·20 (Price factor 4·715 times that of 1913) |
| *1871* | 2·05 | *1925* | 1·84 |
| *1881* | 2·56 | *1930* | 1·56 |
| *1891* | 1·74 | *1935* | 1·25 |
| *1901* | 1·43 | *1937* | 1·45 |
| *1911* | 2·38 | | |

## WOOL

*Historical*

The manufacture of woollen goods in this country is of much earlier origin than that of cotton. For one thing the production of the raw material was indigenous. Guilds of weavers were formed in the City of

London in the time of Henry II and subsequent English kings encouraged the industry from which much of their revenue was derived. The first considerable migration to this country of skilled Flemish and other weavers to escape persecution on the continent dates from the 13th century; and it is interesting to note that 'cloths of worsted' were already famous in 1301. In the reign of Charles II a special stimulus was given by a decree that all corpses had to be buried in woollen shrouds, an enactment that remained on the Statute Book for more than 100 years, though not strictly observed. That wool represented a material source of national wealth in ancient days is emphasised symbolically by the fact that the Lord Chancellor has, as his official seat in the House of Lords, the 'Woolsack'.*

Fine wool from the merino sheep, first produced in Spain, was imported into this country early in the 17th century, and the first importation of these sheep into Australia took place in 1789. Thereafter an enormous impetus was given to this branch of husbandry in the Empire. Later various cross-breeds were introduced, especially in New Zealand where the conflicting claims of mutton and fleeces had to be taken into account by the sheep breeders. As a result of the development of sheep breeding in Australasia and South Africa, as well as in the Argentine, the wool clips from these countries have largely reinforced our indigenous source of supply. English wool, either exported or used in this country, constitutes now about one-sixth of the total supply for this country.

Some stress has been laid on the ancient origin of the industry in this country, because it accounts for the fact that the industry largely consists, at all events so far as processing prior to the finishing end of the trade is concerned, of small units, many of them family concerns many generations old. It has been estimated that 815 of the firms in the spinning and weaving sections of the wool industry have less than 100 employees. These facts, coupled with the horizontal organisation of the industry, have made it like cotton, largely dependent on craftsmanship. Even with the advent of modern machinery the skill of the craftsman plays an important part in the finished cloth.

* From the reign of Edward III till at least the Great Rebellion the judges in 'commercial' courts sat on sacks of wool to signify the nature of the jurisdiction and arising from this practice it had been decreed that the judges should sit on sacks of wool in the House of Lords. In the reign of Victoria, but possibly earlier, the Woolsack became restuffed with horsehair. In 1938 the guilty secret of the Office of Works came to the knowledge of the International Wool Conference which animadverted on the deplorable fact. So with the Lord Great Chamberlain's permission the Conference had it restuffed with about 200 lbs. of a blend of English, Welsh, Scottish, Northern Irish and Dominion wools.

*Nature of the wool fibre*

There is another factor of importance in connexion with research for the industry. An animal fibre is involved and the chemistry and physics of a protein fibre are very different from and more difficult than those of a vegetable fibre. It was relatively easy for the Wool Industries Research Association, for instance, to devise an effective sheep-marking fluid which would disappear during the 'scouring' process, to replace the tar of previous days. But an improvement of processing which entailed knowledge of the structure of the long-chain molecules of the wool fibre involved greater difficulties. Modern advances in X-ray technique have provided a valuable tool for elucidating the general structure of the long-chain molecules of wool. But the 576 units of 18 types which are estimated to form the 'repeat' of the molecular pattern of wool make the problem one of much greater complexity than that presented by the single unit of which cellulose consists. Moreover, several of these individual units (the amino acids) are capable of reacting with others in neighbouring chains thus forming cross links of various degrees of strength. Such combinations account for the remarkable physical properties of wool, and since they are amenable to modification and may even be altered during the ordinary processes of manufacture, they determine the behaviour of the resulting material. To discover the actual chemical explanation for such changes makes exacting demands on the protein chemist. New chemical methods developed in the Wool Industries Research Association laboratories bid fair to provide fundamental methods not only essential for progress in our knowledge of wool but equally valuable in the wide range of biochemical problems.

*Non-shrink process*

Laboratory research is one thing but industrial application of its results introduces an entirely new set of problems. In a highly developed industry in which individual firms are large and progressive enough to develop new ideas from the laboratory stage, competitive enterprise may be relied on to bring about the changes required for modernisation. In an industry of relatively small units its Research Association must take a hand. An example is the work of the Association on that important property of wool which is responsible for 'felting': this is annoying when it causes laundered garments such as socks and vests to shrink, but it is an indispensable property in the making of many types of cloth in which wool has no competitor. The tendency to 'felt' can be largely suppressed by different types of chemical treatment. Various methods based on the use of hypochlorous acid solutions have

long been carried out. Everything depends, however, on the control of such processes, which is difficult, if uniformity and therefore a reliable article warranting the term 'unshrinkable', is to result. The Wool Industries Research Association has developed from many possible methods new processes which have been studied experimentally with the professed objects of providing ease of control and reliability. Already very large weights of material have been treated commercially by one of these—the dry chlorination process—and only the absorption of existing plants in war production and the difficulty of building new plants have prevented a much greater expansion. A further development is the enzyme process evolved by the Association. The enzyme, known as *papain*, has proteolytic properties, and is collected as a latex from the Paw-paw (Carica papaya) in the same manner as rubber latex. In one of its applications it can be used to produce a non-felting finish on wool. In another it is used to remove the scales from the wool fibre after a previous treatment with chlorine or other agent known to reduce felting properties. This treatment results in a silky finish and reduces the well-known and objectionable 'tickle' of wool garments.

Apart from the introduction of new processes a Research Association, with the backing of the industry it serves, can greatly facilitate the improvement of standards of quality. Frequently there is little inducement owing to market conditions to work to improved standards unless a general rise of standards can be brought about. The possibilities of such schemes have been very successfully demonstrated by the Research Association in its control of unshrinkable wool finishes required for service wear by means of the 'Warnorm' Certification Trade Mark (the name of the scheme for a non-shrink process to be applied to all woollen garments supplied to the Forces in World War II.).

As in the case of cotton a good deal of work has been done in improving the machinery used in the processing of wool and the Research Association has made a number of notable advances in this direction.

One of the difficulties in the way of collective effort in research by the industry arises from the fact that there are no less than eighteen trade federations concerned with its many branches. Even so these federations do not include non-federated firms, or such important sections as hosiery, carpets or felt.

### *Overseas interests*

Owing to its large dependence on the overseas supply of its raw material, the industry through its Research Association, has made close contact with the Dominions, and conducts, at their charges, a programme of research on 'wool quality', which is of interest and im-

portance to wool-growing countries. If the sheep-grower can be told what are the essential qualities to produce in the fleece, he will be in a better position to operate in the market for his products and so to benefit as a sheep-breeder. In 1943 the income of the Wool Industries Research Association was £38,633 of which about £9,450 was contributed by the Dominions.

*Production and export*

The following table indicates some of the phases through which the industry has passed since the middle of the 19th century.

| *Year* | *No. of employees* | *Value of Total Production in £ million* | *Value of Export in £ million* |
|---|---|---|---|
| 1851 | 254,000 | — | (1874) 21·1 |
| 1901 | 235,000 | — | 21·25 |
| 1911 | 261,000 | — | 37·6 |
| 1924 | 274,397 | 194·3 | 66·8 |
| 1930 | 228,209 | 114·8 | 40·6 |
| 1935 | 242,200 | 130 | 30 |
| 1937 | 244,900 | 154·9 | 35·5 |
| 1939 | 247,200 | 151 | 26·5 |

*Knitting of Textiles*

Before leaving the principal textiles there is an invention which affects them in an important way, the knitting machine. The hosiery trade is concerned with cotton, wool, silk and rayon. The stocking frame-knitting machine was invented by the Rev. William Lee in 1589 but received scant recognition in this country, and he emigrated to Rouen where his invention was more favourably received. This invention was a singularly perfect one and formed the basis of the knitting industry up to the end of the 18th century. The advent of power machinery and the invention of the self-acting or latch-needle by Matthew Townsend in 1849, to replace Lee's bearded-needle, paved the way for the building of the modern plain and rib circular and flat bar machines and the automatic seamless hosiery machines. Like Lee, Townsend had to seek reward away from this country and both died in poverty. Subsequently various improvements were made, especially in America, in automatic knitting machines by which not only hose but knitted garments of all descriptions are mass produced. The outstand-

ing feature of the development of the knitting industry has been the profound effect it has had on underwear. These machines have made possible a whole range of fabrics with properties which are quite unattainable with woven fabrics.

## OTHER TEXTILES

There are other vegetable fibres made into manufactured products, the chief of which are jute, hemp, ramie and sisal.

### *Jute*

The plant from which this fibre is obtained is grown almost entirely in Bengal and it was not till the middle of the 19th century that it was imported to form an important British industry, centred in Dundee. Used largely in the making of bags and sacks, it is also the fibre used in the coarser types of carpet and for matting. The machinery for processing the fibre is similar to that used for the heavier types of linen goods but owing to its coarse stiff nature it is subjected at an early stage to a softening process with oil and water.

Jute manufacture flourished in Dundee, during the last half of the 19th century; but at the end of that century and during the 20th, Calcutta, the centre of the area of cultivation of the plant, set up an increasing number of jute mills. Thus the export of jute bags from India rose from 56 millions in 1880 to over 200 millions in 1905; and jute cloth from about 5 million yards in 1880 to well over 500 millions in 1905. The Dundee industry has suffered in consequence and it appears likely that the tendency will be in the same direction in future.

The British industry has not formed a co-operative Research Association as in the case of the main textile industries. In recent years research has been conducted for jute both here and in India by two organisations largely centred in Calcutta.

### *Hemp*

The plant from which hemp fibre is obtained resembles in structure a flax plant but grows to a height of about 8 feet. A narcotic drug is obtained from it as well as seed and a valuable fibre that closely resembles flax. The stalks are pulled and 'retted' and the fibre separated from the plant by processes very similar to those used for flax. The fibre is of particular value in rope-making but is also used in the making of canvases. The industry in this country is not a large one and the properties of the fibre and its processing, as well as those of ramie, have been studied by the Linen Research Association.

*Ramie*

Ramie, or China grass, is obtained from a plant of the same botanical family as the stinging-nettle and the fibre from it has been used from early times in China. Degumming and decortication of the plant stalks are difficult and until simple processes at the place of cultivation can be provided, manufacturing use of this fibre is not likely to make progress. The value of ramie lies in its lustre and strength—claims have indeed been made that it is stronger than any other natural fibre. Improvement in the local preparation of the raw material is one of the chief directions in which progress needs to be made, if the growing of this crop is to be profitable. This is also the case with flax in those parts of the overseas Empire suitable to its growth.

*Sisal*

The chief remaining 'hard' fibre is sisal. The fibre is obtained from the leaves of the plant, the growth of which has recently been encouraged in some of our African colonies. It is used for making twine and cord. As in the case of flax, hemp, and ramie, research is needed to find methods for improving the initial preparation of the raw fibre at the place of cultivation. Hemp and ramie are spun on flax machinery with little adaptation but sisal requires special machinery in preparation for spinning.

*Phormium tenax*

Another minor vegetable fibre produced in New Zealand is 'New Zealand flax' (*phormium tenax*) which grows wild in the swampy parts of the islands. Until, however, better strains are cultivated by selection as was done with the pedigree flaxes by the Linen Research Association and until improved methods of decortication are devised, this New Zealand fibre is not likely to be of much importance.

*Government assistance to textile research*

There is a final point to note about textiles in general. They represent a major section of British industry. The value of the total exports of all textiles in 1939 was £92¾ millions. The textile industries, however, receive no assistance in kind from governmental research. The metallurgical industries receive much. The National Physical Laboratory has an important metallurgical department, maintained at a pre-war annual cost of about £30,000; and the Services, especially at Woolwich, conduct research of importance into ferrous and non-ferrous metals. There are no less than ten departments of metallurgy which are integral parts of university institutions. Similar facts are true of the

chemical and coal industries, though not to such a large extent. In the case of the textiles, however, while one or two universities have important textile departments and conduct research of a fundamental character on textile fibres, the industry as a whole in all its manifestations is dependent almost entirely upon its own endeavours and those of its several Research Associations. In the case of the linen industry its Research Association receives State aid not only from D.S.I.R. but also from the Government of Northern Ireland.

# PART II

## RESEARCH FOR THE COMMUNITY

## INTRODUCTORY NOTE

In the modern world and particularly in a highly industrialised and mostly crowded community such as this, the health, happiness and convenience of the people depend more and more on a scientific solution of the problems which inevitably arise. The first needs are two-fold when a sufficiency of food, water and clothing have once been secured. The individual needs first a healthy and attractive home and next, well sited, ventilated and lighted premises in which to work with surroundings as bright and pleasant as possible and provided with facilities for washing and for meals, as well as for drying wet clothes. For all these purposes the aid of modern science is needed and the congeries of crafts and technical processes included in the building industry are involved. This multiple industry is one which touches John Citizen so intimately that building and its problems are best considered under this heading rather than as a productive manufacture in Part I. Other industrial activities besides housing, food and laundering and in particular communications and transport affect the individual almost as closely and are therefore treated in outline in this Part.

Fuel as an essential for the community might claim to be included here but it was thought more convenient to deal with its research aspects elsewhere. Research on fuel is largely bound up with its utilisation by practically every productive industry and the coal survey conducted by the Fuel Research Station is naturally dealt with as a national undertaking (p. 280).

Two aspects of water supply so far as research is concerned are (1) water pollution which is dealt with on p. 285, where the work of the Water Pollution Research Board is outlined, and (2) underground water supplies which are the scientific concern of the Geological Survey (p. 279). In 1937 a tentative beginning was made, with the appointment of an Advisory Committee under the chairmanship of the late Sir Henry Lyons, to inquire into the yield, general behaviour and quality of water sources, chiefly rivers; but it had no powers of initiation, it was hampered by lack of funds and on the outbreak of World War II was suspended. In April 1944 the Ministries of Health and Agriculture

and Fisheries and the Department of Health for Scotland presented a White Paper to Parliament on a 'National Water Policy', from which it becomes clear that as a 'means of ensuring that all reasonable needs for water can in future be met' the existing machinery is inadequate and lacks the necessary power both at the centre and locally for securing progress; that the problem is many-sided and highly complex; that its complete solution will take years of work and a large expenditure of money.

It is encouraging to learn that so careful an analysis of the many factors involved has been made and still more that the Government has decided to apply to Parliament for the necessary powers to press forward with a national water policy, and especially with the work of the national water survey and for the provision of Exchequer grants of £21,375,000 for the extension of piped water supplies and sewerage in the rural areas of Great Britain. The White Paper reveals the opportunities that have been neglected and a comprehensive and systematic study of our rivers has still to be made.

This Part is therefore confined to an account of the progress made by science first in the art and craft of building, second in the evolution of various communication services—air transport and navigation, post office services, radio, railways, shipping and marine navigation, waterways, roads and road transport. Finally food preservation and the laundry service are considered.

# CHAPTER 27
# BUILDING AND TIMBER

*Nature and size of the industry*

That research into problems of building is nationally important is easy to recognise. The capital value of all buildings in this country has been estimated at £4,500 millions in 1927–28 (Sir Josiah Stamp) and at £6,000–£8,000 millions in 1940 (Sir Kingsley Wood on the second reading of the War Damage Bill, December 1940). According to the Board of Trade Census of Production (1935) the gross yearly output of the building and contracting trades was £189 millions. The gross output of works of construction, repair and maintenance returned on the schedule of railway companies, public utility companies, local authorities and Government departments adds a further £166 millions. In the peak year of housing development during the inter-war period (1936) as many as 350,000 houses were built. The magnitude of these figures alone shows how important a place building occupies in the national economy. We want building for our homes, and for our places of work, be they factories, workshops, or offices. Better building means better homes, and more efficient building means smaller overheads in production. What was not so clear in the early days, however, was the possibility of providing in a single research establishment a well-knit organisation for the purpose. The building industry consists of many elements having in many ways little to do with one another. It is essentially an assembling industry. The materials used are many—stones, bricks, cement and concrete, steel and other metals, timber, paints, bituminous products, slates, tiles, glass and so on. The brick maker has little in common with the producer of stone, or the timber producer with the tile manufacturer. Equally, at the assembling end, that of the builder or contractor, one is again faced with many different craft techniques and constructional operations. Was it possible to establish a research organisation which would bring all these different manufacturing and constructional operations under its purview and develop a coherence which alone would give a meaning to its existence? It has proved possible. The key was found by looking at the problem from the functional point of view. Irrespective of the nature of the construction, a building must be efficient for its purpose of providing shelter and necessary amenities for the occupier, whether it is his home or place of work. It must, for that purpose, be sufficiently strong and stable, without being needlessly wasteful of material; it must

be reasonably easy to keep warm; it must not present an undue fire risk; it must be adequately lit both by day and night; it must keep out damp; it must not be noisy and so on. The intimate connexion between building and the interests and welfare of the community as a whole pointed to the necessity for a State organisation of building research and held out a promise of the necessary coherence.

*Official reviews of the position*

The reality of these problems as well as the progress made in the study of them during the last twenty years, is emphasized by the recent Report* of the Interdepartmental Committee on House Construction (The Burt Committee, appointed 1942). The committee was appointed by the Minister of Health, the Secretary of State for Scotland, and the Minister of Works to consider materials and methods of construction suitable for houses and flats in the post-war period. Its report was published in 1944. The general problems, as at the end of World War I, were the necessity for considering alternative methods of construction in view of the probable shortage of normal labour and materials for house building. The Tudor Walters Committee, appointed by the President of the Local Government Board and the Secretary of State for Scotland in 1917, had produced a notable report at that time (1918), but they were limited to the scientific information then available. They had to speak of the problems of warmth and quiet in the houses in somewhat general terms. But by work carried out in the interval, the Burt Committee has been able to deal with them much more precisely. The warmth of a building depends, to a considerable extent, on the degree of thermal insulation provided by the walls, floors and roofs. The better the insulation, the less expensive will be its heating. The correct degree of insulation in the construction is a matter of balancing its initial cost against savings in heating costs. As a result of information now available about the heat transmission through building material and structures, the Burt Committee has been able to suggest, in precise scientific terms, what degree of thermal insulation in the walls, floors and roofs should be aimed at. Again, the committee has set down, in equally precise terms, what standard of sound-insulation should be provided—insulation from the wireless next door as well as, in the case of flats, from footsteps, etc. overhead. Twenty-five years ago the science of sound insulation as we know it today did not exist. Protection from fire is another important question in house design. On the basis of work done in recent years, the committee has been able to suggest what the standard of fire resistance between contiguous buildings should be. It

* Post-war Building Studies No. 1, *House Construction*, 1944.

may be difficult to put a money value to these various suggestions but their importance to the well-being of the community is beyond doubt.

Again the absence of scientific guidance on major design questions was one of the causes of trouble with some of the alternative forms of house construction after the last war. Today we are again faced with the necessity of using alternatives, but the clear guidance that can now be given on basic requirements should be an assurance that alternatives adopted will be reasonably satisfactory. The work of the Burt Committee is being extended to cover functional requirements for types of buildings other than dwellings by the Codes of Practice Committee set up by the Ministry of Works in conjunction with the professional institutions. This committee is, in fact, charged with the duty of arranging for the production of a comprehensive series of codes for building, covering not only functional requirements but also all the processes of construction. It will be the object of the codes to set down, in as precise terms as possible, what is regarded as good building practice.

*Materials and construction*

While research bearing on the functional requirements of buildings must be main items of the work of a building research organisation, much work must also be done on the means for satisfying the requirements. Into this class falls all the work on materials and structures and the problems of construction. Examples of work done on materials are the investigations on Portland cement and lightweight aggregates for concrete.

*Portland cement*

Important fundamental investigations into the constitution of Portland cement have been carried out. The four main components present in Portland cement are lime, alumina, silica and ferric oxide. Though the compounds formed when three of these oxides are taken together had previously been studied, no study had been made of the behaviour of the four oxides together at the temperatures which occur in the burning of Portland cement. The results of this investigation have been accepted in all countries as a contribution of fundamental importance to Portland cement technology. Again, important work has been carried out on the hydration of Portland cement, and the physical nature of the set cement complex. This has important bearings on such matters as the resistance of cements to attack by soils, waters, factory products and wastes.

Little systematic research on cement or its manufacture seems to have been carried out in this country before World War I. The formation of the British Portland Cement Research Association led, during the

few years of its existence, to a study of various phases of manufacture such as fine grinding and the efficiency of kilns. The industry was prompt in developing the manufacture of rapid hardening Portland cement soon after World War I, and later the manufacture of white Portland cement and of high alumina cement was begun. These cements had previously been imported from abroad. In more recent years the industry has in some directions again lagged behind certain other countries, and in consequence various special types of Portland cement which have been available in the U.S.A. and some European countries have not been manufactured here.

*Aggregates*

Lightweight aggregates for concrete are required for many purposes. The first investigations made by the Building Research Station were on breeze and clinker lightweight aggregates. The cause of failures associated with their use were elucidated and tests developed by which unsuitable materials could be rejected. Another important research in this particular field was on the use, as an aggregate, of foamed slag—a by-product of the steel industry. It was shown that this material is a good lightweight aggregate and an attractive alternative to materials hitherto imported from abroad.

The Station has also been responsible for much research on the factors affecting the durability of set cement. This has been a guide to the engineer and the general user. The precautions to be taken in using cement and concrete under many conditions where deterioration may occur have also been determined. The development of new methods of testing cements, which are a more efficient guide to both manufacturer and user, has also formed a valuable part of the work carried out in this country. Similar work has also been intensively pursued in the U.S.A. and elsewhere and much information is now available to guide the manufacturer in the production of cements with any special group of properties. The application of such work to production has unfortunately been pursued abroad more assiduously than here.

*Engineering problems*

By natural development the work of the Building Research Station now extends far beyond the problems of housing with which it was first concerned and includes a considerable part of civil engineering practice. On the engineering and structural side, comprehensive investigations have been made on factors affecting the strength of concrete and methods of testing, on problems of reinforced concrete, on reinforced concrete piles and on the strength of bridges. The biggest developments on the engineering side, however, have been on problems

of foundations and earthworks. Study of these in recent years has resulted in entirely new conceptions of the methods of analysing them. A new branch of applied science has in fact arisen—that of soil mechanics. The initiative came from abroad, but pioneer work in developing the subject has been carried out by the Station. It will be obvious that as all civil engineering work is bound up with the soil, in one way or another, this work is of fundamental importance. Types of civil engineering constructions that have been the subject of enquiry and of subsequent investigation include earth-dams for reservoirs, embankments and cuttings for railways, retaining walls, landslips, settlement of buildings and flood protection schemes.

*Other problems*

Among other problems studied reference should be made to the extensive investigations on the heating of buildings, including studies of different heating systems.

*Co-operation with industry*

The co-operation of industry is vital to the success of the work. The Station has enjoyed much goodwill and the conduct of investigations jointly with the manufacturers of materials, professional institutions and contractors and the pooling of experience thus brought about has been invaluable in developing a common understanding of the problems involved and in arriving at solutions. There is scope for further advances in this direction.

The general objective of all the work done is to establish a science of building. The information obtained in the course of laboratory work coupled with the experience gained in dealing with practical problems is creating a new perspective. Building is a traditional industry, and there is much to be done to bring it abreast of modern scientific and technical knowledge. This is particularly important in view of the number of new materials and methods now being used. Reference has already been made to one or two significant indications of the progress in the past twenty years. Perhaps the most significant of all is the fact that the Station felt it possible a few years before World War II to plan the production of a series of volumes bringing together all its accumulated experience under the title 'Principles of Modern Building'. The first volume published has been accepted as a valuable contribution to the literature of building.

During World War II, the accumulated experience of the Station has been of undoubted value in dealing with the many problems created by shortage of normal building materials—how best to economise in their use, what alternatives could be employed and how. This has been its

main contribution during the war. It is, however, interesting to note that the experience and technique gained have been applied to wartime problems quite unconnected with building. For instance the normal process for the production of superphosphates as fertilisers makes heavy demands on supplies of sulphuric acid. Investigation at the Station has produced a kiln process for the conversion of insoluble mineral phosphates into a soluble form suitable for fertilisers, and full-scale production is to be arranged.

## TIMBER

One of the materials most widely used in building is timber and the scientific study of the nature, seasoning and preservation of different kinds of timber for various purposes has been undertaken by the Forest Products Research Laboratory of D.S.I.R.

The Laboratory has undertaken basic investigations into methods of drying timber naturally and artifically by the design of kilns suitable for this country and by the preparation of schedules of drying for all species and sizes of timber. It has studied the design of wood-working machines so as to reduce the number of patterns and to improve the action of saws and cutters. It has also studied the relation of the anatomical structure of different timbers to their physical properties as a guide to the growing of timber in this country. Means have also been devised to prevent insect attack in timber and manufactured articles. Special investigations have, in particular, been undertaken with an immediate bearing on the building industry. Soft woods so largely used have been graded by determining the effect on strength which natural defects such as knots, etc. produce. Appropriate sizes for joists, rafters and the like have accordingly been tabulated and economical designs made for timber construction.

The need for preserving constructional timber against decay and insect attack has led to tests of preservatives and examination of the most economical amounts to be used and the best methods of application. The life-history of dry-rot has led to measures for its prevention, and materials for 'fire-proofing' timber and the methods of their application have been studied. The resistance of flooring timbers to abrasion and the relative values of different species and floor finishes have been investigated and finally the properties of different adhesives used in joining wood and their behaviour under climatic changes have been examined.

### *Other industries assisted*

Much of the work at the Laboratory is of interest to many industries other than building. The study of plywood manufacture, for instance,

is important for the building of aircraft and boats. The suitability of new species, particularly those from the colonies, has been tested. The Laboratory has also developed special forms of construction including a new method of making bent laminated members.

Mining, railways and agriculture have benefited from work of the Laboratory on the preservation of mining timbers, sleepers, poles and fencing. For the packaging industry, savings up to 50 per cent in weight and 20 per cent in stowage space have been secured by the scientific design of containers, with additional protection of the contents. For instance, casualties in eggs have been reduced from 40 to 4 per case. Corrosion of metals packed in wooden cases has also been prevented.

A long list of benefits for miscellaneous industries could be compiled. It would include: Use of new timbers for pencils; improvements in machinery for bungs and shives; substitutes for cork for stoppers; woods for vat-making; decay in vats; wood taint in liquors; decay in refrigerating ships; and bent work in sports goods and furniture.

All these industries involve the production of a large quantity of wastewood and this fact led the Laboratory to attack a problem which had hitherto received little attention. A simple charcoal kiln was designed which can be worked by unskilled labour with the result that the country has been self-supporting in charcoal throughout World War II. Furnaces have also been developed to make use of sawdust as a fuel and to show that sawdust can be used for cattle fodder as a reserve food in case of need. This work opens up the possibility of using the large reserve of many kinds of timber in the tropical colonies as a means of enlarging or creating a cattle population in those countries. But more research will be necessary on this possibility, for the use of timber as a cattle food cannot become economically profitable unless a paying use can be found for the resulting effluents.

# CHAPTER 28

# COMMUNICATION SERVICES

## AIR TRANSPORT AND NAVIGATION

It is likely to be some time before the well-to-do individual, apart from the enthusiast, keeps his private aeroplane as he does his motor car, though it would be a rash thing to say that it is never likely to happen. Consequently aircraft construction is more appropriately dealt with in this Part of the book than under the productive industries, in the same way that locomotive construction is touched upon below. The influence of the Aeronautical Research Committee has been very great (see p. 296.)

### *Early years of aircraft construction*

Wilbur and Orville Wright made the first successful flight in a heavier-than-air machine in 1903 when they flew 260 yards; nearly two years later they flew 24 miles at a speed of 38 miles an hour. Blériot flew the English Channel in 1909. The progress made in the succeeding thirty odd years has had but few parallels in the development of an industry by scientific endeavour and is due to the impact of the two World Wars. The aircraft industry in this country may be said to date from 1915; its history though brief is of great interest. The national importance of the industry can hardly be exaggerated. Command of the sea has been these islands' safeguard from the time of King Alfred and command of the air above them is now equally essential if they are to remain unconquered; but the aeroplane is now seen to be no less important as a means of communication.

### *Growth of the industry*

The growth of the industry and its forced progress is an instance of the way this country, under stress of circumstances, can surmount obstacles and overcome difficulties created, to a large extent, by the lack of planning and organisation in times of comparative leisure. In 1915 the construction of aircraft was mainly in the hands of a few of the early enthusiasts, the greatest and most original of whom were the brothers Wright. The design of these planes was based in the main on commonsense and experiment. The Royal Aircraft Establishment, called at that date the Royal Aircraft Factory, was the only centre in this country where full-scale scientific experiment was conducted and it not only carried on pioneer research but designed airframes, engines

and instruments. These were the early days of World War I. In 1916, the newly-born industry rebelled against the position occupied by the Government establishment, accusing it of stifling originality of design. There was probably some justification for the contention that the approach to industry was not wisely made nor with that understanding which is all important in such collaboration. At that date, however, the R.A.E., to give the Royal Aircraft Establishment its usual short description, was the only centre in the country which had made substantial scientific investigations and could provide data for sound design in matters of stability and control. It had produced excellent designs for aeroplanes and engines and one of its models was acknowledged to be one of the very best of its era. But the unrest in the industry brought about a Government enquiry which resulted in an undertaking that the R.A.E. should cease to design planes and engines and confine its activities to experimental and testing work.

The close of World War I produced a serious position in the young industry. Cessation of Government orders for war purposes and the absence of peace-time orders to replace them, caused the aircraft builders grave financial difficulties. Moreover there was little or no scientific direction at headquarters. Professor Bertram Hopkinson, who had built up the Government's experimental organisation, had been killed in an accident and others had returned to their civil occupations. The director of research at the Air Ministry was an army officer.

*Development by Government*

Considerable changes were made in 1924 on the appointment of a Director of Scientific Research at the Air Ministry. Since the Government was the only purchaser of planes and it was essential in the national interest to keep a number of firms in sufficient activity to form a source of supply to the R.A.F., the modest sums voted by Parliament for the purpose were distributed amongst the firms with but little continuous business for each. The adoption of a successful design by the R.A.F. resulted in a spasmodic period of prosperity for the firm concerned till another design was favoured when the first firm fell once more into difficulties. Such conditions led to great rivalry among the firms and a complete absence of co-operation. Owing to the lack of a reasonable period of prosperity, no firm could build up and retain a satisfactory staff. Considerable sums are needed for conducting the essential researches on which improved designs can be based. Expensive equipment and highly skilled brains are required and no firm was operating on a sufficient scale, even in the temporary phases of prosperity, to face the necessary outlay. The result was that the Government, by means of the R.A.E., had to spoon-feed the industry with the results of its own

scientific work. Being thus subsidised in cash and kind, the industry was able to make but small efforts to help itself, still less to form any co-operative research organisation of its own.

Probably the greatest disability under which the industry suffered was the absence of any civil outlet for its products. Such demands as existed were for small sporting machines to be used by amateur enthusiasts. The conditions in this country were not then favourable to public civil aviation. Weather uncertainty and the relatively short distances to be covered gave little chance for air travel in competition with rail and road facilities. In a country like the U.S.A., the conditions are entirely different and the long-distance journeys to be travelled there furnish ample opportunity for the development of aircraft undertakings. The Empire Service called for only a limited number of planes and the Government itself was directly responsible for their provision.

*Industrial developments*

From about 1930 the increased needs of the R.A.F. brought about better conditions in the industry and the flow of orders for that purpose brought larger funds to the command of the firms, but there was no expansion possible as a result of any demand for civil aviation. For military requirements several firms undertook more and more experimental work and a number erected their own wind tunnels. In the aero-engine field some four or five firms developed strong and highly efficient research and development departments and one or two were able to establish a useful export business.

Such was the position when the threat of World War II appeared. It was obvious that the country was in no position to compete with Germany in the air so far as numbers of planes were concerned. The British planes though good in quality were lamentably short in quantity. Aircraft construction, as a part of national defence, had been put aside until the last moment and attention had been confined to the scientific investigation of engines and the problems of flight. The narrow margin of safety which resulted was shown during the Battle of Britain. Had it not been for the quality of the planes in existence at the time and the intrepidity and skill of the men who flew and fought them, the result of the war might have been different.

Under the stress created by the growing likelihood of a war which might well be determined in a rapid and decisive fashion by action in the air, the shadow factory scheme was hurriedly devised, under which new factories were built and equipped at Government expense and operated under the direction and management of firms to produce planes in quantity from existing designs. In the late 1930's certain large engineering concerns also embarked on aircraft production, either by

taking over small aircraft firms or by setting up production factories of their own to build planes according to established designs. Under the pressure of actual war, the industry grew into a vast net-work of sub-contracting firms spread over the whole country.

*Recent developments*

During the years of World War II great developments occurred in aircraft construction. The British types of plane which formed the back-bone of the R.A.F. in 1939 have all been superseded either by improved forms of those bearing famous names or by entirely new models. In 1939 the typical British single-seater fighter was a monoplane with a single rifle-calibre gun. Five years later the first-line fighter was armed with shell-firing cannon and by 0·5 inch machine guns, while many carried in addition rocket-projectors. Moreover, the modern fighter could carry bombs up to 1,000 lbs. in weight. In spite of the added load, performance improved owing to the more powerful and efficient engines with which they were fitted. One famous single-seater fighter despite an increase of 40 per cent in all-up weight, was 35 per cent faster than its 1939 predecessor with a rate of climb 80 per cent better. The power of the engine had been doubled. A heavy bomber in 1939 could carry a bomb-load of 1·2 tons; in 1943 its load was 4 tons and its effective radius had grown from 600 to 1,500 miles. The huge under-carriage required to support the giant bombers on the ground called for light-alloy forgings up to 250 lbs. in weight. The twin-engined fighters were developed in several directions; as night-fighters, as torpedo-planes, as photographic reconnaissance aircraft and as fighter-bombers. Though carrying very heavy armament, speeds of more than 400 m.p.h. could be achieved. Far higher speeds are attainable by the new British jet-propelled planes.

Airscrews of the two- and three-blade types were replaced by four- and five-blade airscrews and by contra-rotating six-blade units. These can be feathered to present the least possible resistance when an engine is stopped and the pitch of the blades can be adjusted by controls under the pilot's hand. Great strides were made in engine developments. The power of single units grew from some 1,100 h.p. in 1939 to more than 2,000 h.p. in 1944. All manner of armament equipment was also improved.

Except for multiplying the number of cylinders, the development of the reciprocating piston engine may be assumed to be approaching its limits. It appears likely that an output of some 3,000 b.h.p. will be attained, but above that figure the jet unit promises a better solution. Great Britain has played a leading role in this field, the Whittle power plant being the first successful example of its type to go into service. The simplicity of the jet unit is attractive, but unfortunately its

fuel consumption is high. The only way to reduce it is to use compressors, but as these can be driven by turbines working in the stream of burning gases, there is no need to introduce reciprocating parts, and even with compressors the direct-reaction power plant is likely to be much simpler than any type of reciprocating piston engine. It may well be that an intermediate stage will see a combination of jet and airscrews, the latter being driven by internal combustion turbines. The great advantage of jet propulsion is that its efficiency increases with speed and height so that it is particularly suitable for very fast aircraft. At low speeds it is inefficient.

As the White Paper on 'Statistics relating to the War Effort of the United Kingdom' published in November 1944 showed, the increase in aircraft production was enormous. At the end of 1939 the total deliveries of new aircraft were at the rate of 730 a month and 25 per cent of them were trainers. By 1943 the average rate of deliveries was trebled and as measured by structure-weight, nearly six-fold. In the first six months of 1944, 2,889 heavy bombers were delivered as compared with 41 in the whole of 1940. Fighters increased from 110 a month in 1939 to 940 a month in the first half of 1944.

These figures take no account of aircraft repaired and reconditioned nor of the construction of spare parts which represent 50 to 60 per cent of the output of complete aircraft. For every 6 new aircraft produced in 1943, 4 aircraft underwent reconditioning. The output of aero-engines and aircraft components was even greater than that of air-frames. Engine output increased from 1,130 a month at the end of 1939 to an average of 5,270 a month between January and June 1944. The following extract from the tables of the White Paper quoted brings out some of the features of these remarkable achievements:

| | *Sept.–Dec.* 1939 | 1940 | 1941 | 1942 | 1943 | *Total Sept.* 1939–*June* 1944 |
|---|---|---|---|---|---|---|
| Total new aircraft - | 2,924 | 15,049 | 20,093 | 23,671 | 26,263 | 102,689 |
| Structure-Weight (million lb.) - | 11·26 | 58·84 | 87·26 | 133·36 | 185·23 | 587·7 |
| Aircraft repaired - | — | 4,196 | 12,131 | 16,636 | 17,932 | 60,099 |
| Aero-engines delivered | 4,532 | 24,074 | 36,551 | 53,916 | 57,985 | 208,701 |
| Engine horsepower (million h.p.) - | 2·9 | 17·4 | 31·42 | 59·45 | 72·8 | 225·89 |
| Aero engines repaired | — | 6,726 | 20,177 | 27,567 | 35,832 | 113,005 |

### *Civil aviation*

Civil aviation as such came almost to a standstill with the outbreak of World War II. A great deal of air transport was, however, carried

on for military purposes and vast quantities of war material were transported, in addition to large numbers of passengers travelling on urgent war business.

For the sake of post-war development it was unfortunate that Great Britain had to concentrate entirely on military aircraft types. The United States, on the other hand, foresaw the need for air transport in the war and built huge numbers of transport aircraft. Many of these can readily be converted for post-war civil use, whereas Great Britain will have to start almost from scratch. That will probably mean the use by many nations of American commercial aircraft in the immediate post-war period, but on the other hand this country can plan advanced types to come into service later. Our designers and constructors are well capable of producing the types, but it must of necessity be a couple of years before they can go into service. First to be opened after the war will be the Empire air routes on which very probably several specialised types of aircraft will be used. For instance, very fast jet-propelled aircraft would be suitable for carrying mails, which occupy little space in proportion to their weight. Passenger-carrying aircraft would need larger fuselages or hulls and would, therefore, be rather slower. Designs are ready also for freight-carrying aircraft in which economy is the main consideration and great speed relatively unimportant. For the very largest aircraft it appears likely that the flying boat type will be used, since landplane undercarriages and runways present serious problems at weights above 100,000 lb.

*Air services*

The extent to which air services have been provided by United Kingdom companies is shown in the following table.

REGULAR SERVICES OF UNITED KINGDOM COMPANIES

*including internal services, services between U.K. and Continent, Bermuda–New York and services operated by Imperial Airways Limited on Empire routes*

| | *Aircraft stage flights* | *Passengers* | *Cargo (mail and freight) tons* |
|---|---|---|---|
| 1928 | 4,800 | 27,300 | 813 |
| 1934 | 51,600 | 135,100 | 1,422 |
| 1937 | 87,500 | 244,400 | 3,961 |

The relative provision of air services by the principal nations in 1937 is also of interest.

| | *Route mileage* | *Passengers* | *Cargo (mail and freight) tons* |
|---|---|---|---|
| British Empire - | 85,012* | 460,349 | 27,843 |
| France - - | 37,387 | 79,864 | 1,745 |
| Germany - - | 25,968 | 320,600 | 8,070 |
| Italy - - - | 19,665 | 113,743 | 2,687 |
| Netherlands - | 18,975 | 138,178 | 2,406 |
| United States - | 63,656 | 1,267,580 | 13,277 |

* About two-thirds of this mileage were operated by Dominions, Indian and Colonial companies.

*Air navigation*

Up to 1924, nearly all commercial air routes lay overland with many aids available for determining the flying craft's position, but from that date the crossing of large stretches of the ocean has become common not only for military but for civilian purposes and the difficulties of navigation have been greatly increased.

The aero-compass was the first necessity for any long-distance flights and the magnetic compass was, it is believed, first tried out in a plane flown for the Admiralty in 1909 and piloted by Cody. The difficulties were extreme but ultimately the aperiodic aero compass was developed. Later the master magnetic tele-compass was produced and placed in the wing or the tail of the aircraft to reduce local electro-magnetic disturbance. A repeater is fitted where required. A still later development is the astro compass which is based upon the principle that given the latitude and the local time, the direction of any celestial body is known and the compass card can be set to agree with it.

Other instruments carried are the altimeter, which, owing to hysteresis, often gives only approximate readings and hence at low heights cannot ensure safety from high objects such as buildings, pylons, etc.; the hysteresis effect has, however, been largely overcome by the use of suitable alloys. Artificial horizons, turn and bank indicators and automatic pilots are also in use. Radio bearings can be taken but they are increasingly inaccurate at long distances and so is dead-reckoning. Wind-drift over the sea is difficult to measure, especially when flying above cloud. The aircraft sextant carries its own horizon and may be used above the clouds by day or night. It weighs less than 5 lb., and in large airplanes has an accuracy to within 5 miles. Attempts are now actively in progress to devise an air echo-sounder and a cathode ray compass. The latter depends on the deflexion of an electron stream by the earth's magnetic field: echo sounders are also referred to on p. 163 and p. 229.

A more recent and, so far as defence is concerned, a most important development is in the field of radio. 'Radar' is a new method of detecting aircraft and ships first made public in June 1941. It was an application of a well-known method to a new purpose. For years a radio-pulse technique had been used to ascertain the height and electric character of the higher atmosphere—the so-called ionosphere. As the result of pioneering research in the radio division of the National Physical Laboratory begun on the suggestion of the Directorate of Scientific Research at the Air Ministry, a series of experiments was undertaken with the approval of a special committee of experts, the results of which were seen during the Battle of Britain. The success was due to the amazing power of amplification without distortion which modern radio methods can achieve. Radio inventions of this kind will undoubtedly be invaluable to civil aviation after the war for they will enable the position of incoming air liners to be ascertained even in adverse weather conditions and equally make it possible for planes to avoid collision in cloud or thick weather. A radio location station can locate all incoming aircraft and direct them to their precise destinations. On a plane in flight the outline of the land below can be thrown up on a screen, much in the manner of ordinary television though with less definition. Images can be seen of a landscape, an approaching aircraft and ships at sea, in spite of atmospheric conditions and by night as well as day.

Great progress has recently been made in the mechanisation of all apparatus for air (and marine) navigation.

## POST OFFICE SERVICES

### *Postal Services*

Until the time of Charles I the possibility of communicating by letter with other people in this island depended entirely on private action, though the necessity of keeping in touch with ambassadors and troops abroad had been met by official despatches from the Government which could be accompanied in special cases by private communications from individuals in touch with the Government. In 1607 Lord Stanhope had been appointed Master of the Posts and Messengers and in 1619 an independent 'Postmaster General of England and for foreign parts' was appointed which led to long litigation with the Stanhopes. But these were at best very imperfect and slow devices which the growing links between England and Scotland in particular were making obvious. Accordingly in 1635 the King issued a proclamation which began thus: 'Whereas to this time there hath been no certain or constant intercourse between the kingdoms of England and Scotland His Majesty hath been graciously pleased to command his servant Thomas Witherings Esquire,

His Majesty's Postmaster of England for foreign parts, to settle a running post or two to run night and day between Edinburgh in Scotland and the City of London to go thither and come back again in six days.'

The service, which was available to private individuals, had soon to deal with 26,000 letters a week. There were no trunk roads as we understand them. Wheeled vehicles were lumbering horse-drawn wagons or coaches on muddy or dusty and pot-holed ways generally little better than tracks worn by travelling cattle or farm carts except where the route coincided with the remains of the old Roman roads. So the post and all quick communications had to be horse-borne. And this lasted till the end of the 18th century.

But at the best this means of communication was too slow for really urgent messages and not safe enough for troops and civilians shut up in a besieged fortress or for ships on the high seas. This led to the adoption of the pigeon post chiefly for military purposes. The use of trained homing pigeons to carry messages dates from Old Testament times and the names of the victors at the Olympic Games were sent by pigeon to the cities of Greece. Perhaps the most systematic use of the homing pigeon on record was during the siege of Paris in 1870 when the messages were greatly lengthened with the assistance of photography and duplicated by the despatch of copies by balloon. In World Wars I and II much use was made of the carrier pigeon, the breeding and training of which had been greatly encouraged by a number of private societies. But after all the pigeon post has only a relatively occasional and highly specialised purpose. Regular postal services depend upon the General Post Office.

Today the British Post Office deals with 20 million letters every twenty-four hours sent to every part of the world. By 1784 the mail coach with its greater carrying capacity and the improved surfacing of the main roads replaced the mounted post-boy and by 1846 the development of a national railway system abolished the last mail coach, between Norwich and Newmarket. Today the scientific construction of our highways and the substitution of the motor for the horse has brought back the carriage of mails by road over moderate distances as a faster and more frequent service than is possible by railway. But for long distances, though the trains hold the field, it finds a growing competitor even in this country in the aeroplane which before the war was increasingly used, especially where the journey involved a crossing of the sea. The railway, however, offers advantages besides those of speed and regularity. The travelling post-office is the chief of these. The mail train between Euston and Aberdeen takes 11½ hours in peace time and on the journey a staff of some 50 sorters deals with an average of 130,000 letters. But this is not all. In order to avoid the

congestion on the streets of London the Post Office built an underground electric railway of its own running 80 feet below the surface with a series of stations for the reception and delivery of mails. There are no drivers or guards or passengers, for the trains are automatically controlled. These run about 1,250,000 miles a year and carry about nine million mail bags. The time taken for correspondence to pass through the hands of the Post Office has also been greatly reduced by the introduction of many mechanical and electrical devices within the sorting offices themselves.

In the year of the Great Plague the staff of the Post Office in London was 47. Today, exclusive of telegraph and telephone services, it numbers over 31,000.

It is for Empire communications that the aeroplane is destined to take the leading role. In 1934 it was decided that the ultimate aim should be to transfer from surface transport to the air the whole of the first class mail (letters and postcards) to and from the various parts of the Empire. In 1937 the Empire Air Mail scheme in co-operation with the Dominions and Colonies inaugurated a service to East and South Africa and the carriage of air mail was made a normal feature of postal operation. In 1938 the scheme was extended to Empire countries between here and India, Malaya, Australia and Hong Kong. Letters for New Zealand went by sea from Sydney. For all these services the charge was 1½d. a half-ounce for letters and 1d. for postcards; the time was cut from a month to 10 days for Australia, from 14 to 3 or 4 days for India, from over 14 days to 5 or 6 days for South Africa, and from three weeks to 4 days for East Africa. In 1939 air mail was carried across the Atlantic. The latest development is the airgraph system, a direct result of the war. The photographic films can include 1,700 letters weighing 5½ ounces as against the 30 lb. which the original letters would have weighed. This service, first introduced for the Forces in the Middle East, had been extended by January 1943 to nearly 30 countries and territories and had carried some 80 million messages.

### *Telegraphs*

The enormous expansion in the industrial and commercial activity of the country, accompanied by the rapid growth in the population, was a great impetus to the adoption of any means science could offer for greater speed in the sending of urgent messages. This acceleration came with the introduction of the electric telegraph, the telephone and finally the wireless transmission of both signals and speech.

The calls for the most rapid communications possible arose as in so many other directions from the needs of national defence. The first attempts to extend the range of communications were made by Napo-

leon, who set up flag and semaphore stations for the purpose. These were a great advance on the primitive use of drums in the African bush or beacons on hills as used in Elizabethan England, for, as compared with the beacon, they made the sending of messages possible. The devices were soon adopted by this country which had long used flags for messages from ships. There was a line of semaphore stations between Portsmouth and London in Nelson's time which he used for communicating with the Admiralty. Today simplified semaphores combined with coloured lights survive only on our railways and here too they are gradually giving way to improved colour signalling. But all systems that depend on direct sight or sound had obvious limitations both in range and speed and rapid communication between distant points only became possible with the invention of the electric telegraph, introduced in this country about 100 years ago. The speed of communication was at first strictly limited. The invention of the Morse Code invented by Samuel Morse, combined with the Wheatstone transmission key and paper-tape recorder at the receiving end first made telegraphy a commercial possibility. Incidentally the Morse Code gave a new lease of life to visual signalling by means of flags and lamps and made the heliograph possible for military purposes.

Technical improvements increased greatly the capacity of each telegraph wire, and the simultaneous transmission of messages on a single wire rose gradually from two to eight and over telephone trunk circuits to 36. The Creed receiving perforators and Creed printers automatically converted the Morse alphabet into ordinary typescript. By 1920 all busy telegraph routes were equipped with the Baudot Multiplex type-printing system originally installed on the London-Paris service, but this soon gave place to teleprinter equipment on all busy circuits. On circuits where the cost of the new equipment was not justified Morse was used on the telephone combined with type-writer reception.

### *Submarine cables*

The story of the submarine cable would fill an important chapter in the history of telegraphy, full of adventure and romance, of failure and of ultimate success which was largely due to British scientific research and tenacity. Only a few outstanding episodes in this development can find a place here. The first submarine cable across the Channel to Cap Gris Nez was laid in 1850 and the first Atlantic cable in 1866, after repeated failures, by S.S. *Great Eastern* under the supervision of Lord Kelvin. When a cable had once been successfully laid its chief enemy was the *teredo*, a small 'auger' worm with a taste for cotton yarn and gutta percha, both used as insulating materials. Sir C. S. Bright, who was personally responsible for the laying of the Persian

Gulf cable, overcame this difficulty by adding powdered silica to the cable's outer covering. Another cause of failure was break-down by vibration and this was largely removed later by a new lead alloy for sheathing introduced by the British Non-Ferrous Metals Research Association which has been adopted by the Post Office for cables and by the Admiralty for cable used in the Navy (see p. 100). Technical improvements, some of which are referred to above, have greatly added, not only to the speed but to the reliability of the services. In 1872 it took 21 hours to send telegrams between Sydney and London. In 1924, at the opening of the Wembley Exhibition, a message sent by King George V took 80 seconds.

The efficient translation of the signals transmitted by submarine cables was greatly enhanced by the inventions made by Kelvin, notably the mirror galvanometer which revolutionised long distance signalling and electrical testing on board ship. The Kelvin syphon recorder had been introduced in 1870 and since the close of the century the 'relay' device, later improved and made much more effective by the 'regenerator', enabled direct signals to be sent over a series of long distance cables without re-transmission at intermediate points. The discovery in 1924 of the magnetic properties of an iron-nickel alloy as a wrapping for the copper-conductor raised the speed of cabling to about 1,500 letters a minute, and the sending of four or more messages at once through the same cable was made possible by the device of the 'channel distributor' which separates the messages and directs them to the appropriate receiving instruments.

The submarine cables to the continent were taken over from private companies by the Post Office in 1889, and later the cable service was supplemented by wireless links worked from the Central Telegraph Office, London. The Post Office controls one of the most powerful radio stations in the world, which broadcasts British official messages and copyright messages for various press agencies. Time signals are broadcast throughout the world from Greenwich Observatory, enabling mariners to obtain their correct longitude.

### *Telephones*

When Graham Bell, a Scot living in the United States of America, exhibited in Glasgow the telephone he had invented, Sir William Preece, Chief Electrician to the Post Office, induced his Department to obtain Treasury sanction to hire sets of Bell's instruments and to supply them at a charge to private wire renters. That was the beginning of a public telephone service in this country, but progress by the Post Office was delayed by Treasury fears of the expense involved. Consequently the development of telephoning over the greater part of the country was

carried out by private companies on a royalty basis and it was not until 1912 that the whole service was taken over by Government, though the Post Office had acquired in 1905 the telephone service for London by agreement with the National Telephone Co. From 1921 onwards development was rapid. Automatic exchanges were gradually introduced and underground cables were laid as the result of the fitting of amplifiers in the circuits which enabled wires of much smaller gauge to be used with a great saving of copper. In fifteen years the whole of the long distance lines (except those in sparsely populated areas) had been placed underground. Transmission was thus greatly improved, maintenance was less costly and faults much reduced. The design and efficiency of telephone instruments and other apparatus supplied to subscribers have also been much improved.

A problem arising in telephone cables is that known as capacity balancing. Telephone cables usually include a considerable number of twisted pairs of paper-covered wires inside a lead sheath, each pair carrying a different circuit. If the symmetry of each pair is perfect, it will be impossible for currents in one pair to induce currents in another pair and thereby cause overhearing or crosstalk between different circuits. Manufacturers are required to keep the symmetry of the pairs as accurate as possible in each factory length but handling and laying tend to degrade the symmetry; further, joining lengths together indiscriminately may give rise to cumulative asymmetry enough to cause serious overhearing. In trunk cables, this is overcome by 'Cable Balancing' and is done after laying but before jointing cable lengths. The degree of asymmetry of every pair in each length, measured as 'capacitance-unbalance', is scheduled and, in joining adjacent lengths, pairs are selected so that the asymmetry in one length tends to neutralise that in the next length. When all lengths are joined up in pairs, pairs of lengths are treated in a similar manner, and so on until the entire cable is joined up. In certain cases, artificial unbalances are added to correct the unavoidable asymmetry of the cable.

### *Wireless telegraphy*

The first attempts to use wireless for commercial purposes were made by Marconi, who succeeded after long experiment in sending messages between the General Post Office and the Thames Embankment. But the fundamental discoveries that lay behind this practical application were the result of the researches of Clerk Maxwell, Heinrich Hertz and others and at a later date by Sir Oliver Lodge and Professor (later Sir Ambrose) Fleming. (see pp. 210–211).

By 1901 intercommunication by wireless was established between Poldhu in Cornwall and Newfoundland and the first commercial service

was installed between Ireland and Canada in 1907. This led the way to the world-wide system of wireless circuits of the present day. But here again, as with the land and ocean cables for telegraphy and telephony, the original speed of communication was increased by subsequent developments. In 1923 the possibility of using short-wave transmission was discovered and wireless then became a practicable alternative to the submarine cable. Short-wave wireless was not only speedier but cheaper for it required far less power in the transmitting station. Once again it became necessary to nationalise the many private interests that had grown up, and as the result of an Imperial Conference held in 1928 the responsibility for cable and wireless links other than those in the hands of the General Post Office was transferred to a single company, Cable and Wireless Ltd., working in close co-operation with the Government. Thus not only are further technical improvements facilitated, but the cost of sending messages is much reduced.

*Wireless telephony*

In 1927 a commercial radio service to North America was opened which led to world-wide service, including all ships equipped with suitable apparatus. 'It is now possible to communicate from Great Britain with more than 93 per cent of the world's telephone subscribers', reported a Special Committee on the Post Office in 1932. This was due to the design and construction in the Midlands by the Post Office of the first high-power station to use thermionic valve transmission.

This country, as the foregoing sketch shows, has no reason to be ashamed of the part it has played in the history of communications by post, cable or wireless, either on the scientific, technical or commercial side. Since the beginning of World War II the advances made here in the field of wireless have been even more remarkable.

## RADIO

*Early years*

In 1869 a Select Committee of the House of Commons considered the Telegraph Bill, which was to enable the Postmaster General to purchase the private companies transmitting messages by electric telegraph in the United Kingdom. During the enquiry, a member of the Committee asked a witness—the engineer of one of the companies—whether he thought a system would ever come into use which dispensed with 'posts and wires'. The reply was categorical—'I do not think it is possible, in fact, I know it is impossible.' This is probably the first reference to wireless telegraphy in official papers and provides another example of the danger of prophecy where science is concerned.

Some six years before this date Clerk Maxwell had propounded the electro-magnetic theory of light, but it was not until 1887 that Heinrich Hertz demonstrated experimentally the existence of vibrations slower than those of light or of heat, the possibility of which Maxwell had predicted. A few years later Sir Oliver Lodge transmitted signals by electromagnetic waves and at about the same time Marconi demonstrated to the British Post Office his system for transmitting and receiving wireless messages and was provided with facilities for developing it here. At first messages could only be sent a few yards but by 1898 a distance of 12 miles was covered, and a year later messages were exchanged across the English Channel. By 1901, thanks to the independent pioneer work of Admiral of the Fleet Sir Henry Jackson, F.R.S., twenty-six ships of the Royal Navy had been equipped with this new means of communication and in the same year Marconi transmitted the letter 's' from Cornwall to Newfoundland.

By 1912 the Marconi Company was conducting a commercial service between Clifden in Galway and Glace Bay in Canada and another large station at Carnarvon, for communication with the United States was in course of construction. Radio communication between ships at sea and the shore had begun and the importance of wireless as a means of saving lives at sea was becoming widely recognised. Thus by the beginning of World War I a wireless or radio industry, as it was beginning to be called, had been established, based on the application of the fundamental researches of such men as Maxwell and Hertz, who had set out to extend knowledge without any thought of its industrial application.

*First applications*

In these early applications apparatus followed very closely that employed by Hertz in his laboratory experiments. Marconi generated his radiations by allowing a condenser charged by an induction-coil to discharge across a spark gap introduced into a length of wire. His first great advance came from earthing one of the lengths of wire attached to the spark gap and extending the other vertically to form an aerial. His receiving apparatus consisted of a glass tube containing iron filings, in its turn connected with a battery and telephone receiver. This apparatus, known as a coherer, acted as the detector and depended on the fact that the incoming waves changed the resistance of the iron filings and so caused a noise to be produced in the earpiece of the telephone. It was soon found, however, that it was better not to introduce the spark gap directly into the aerial but to excite the aerial by inducing oscillations through the mutual action of coils placed in a closed circuit containing the spark gap and condenser, and in the aerial circuit. This allowed use to be made of the principle of tuning which had been discovered by Lodge.

In this type of transmission each time the condenser broke down, groups of high frequency currents oscillating at a rate of perhaps 100,000 a second, were set up in the aerial circuit. The high frequency oscillations in each of these groups practically died away to zero before the next group began and the groups followed each other at a rate of about 100 to 1,000 a second. By means of a key in one of the transmitter circuits the dots and dashes of the Morse Code were produced. Up to 1914 the spark system was gradually developed and larger and larger powers were introduced into the aerial. The Carnarvon Station was designed for 300 kw. while it was commonly accepted that it might be essential for a high speed service to use powers of perhaps 1,000 kw. if a continuous service under all conditions was to be guaranteed.

*First thermionic valves*

Various improvements were made in the detector and in 1904 Sir Ambrose Fleming found that if a hot wire filament surrounded by a metal sheath was placed in an evacuated glass bulb the arrangement allowed electric current to flow in one direction but not in the other, and could thus be used as a detector of wireless waves. This apparatus was the first of the thermionic valves and was known originally as the Fleming Valve but is now referred to as the 'diode' since it had two electrodes. Dr. Lee de Forrest in 1907 introduced a third electrode in the form of a metal grid between the hot wire and the sheath. This three-electrode valve or 'triode' provided a means not only of detecting waves but of amplifying the signals received; and, by leading back energy from a circuit connected between the third electrode and the filament to a circuit between the grid and the filament, it provided an excellent means of generating high frequency oscillations. Probably the most important achievement in communications during World War I was the development of the thermionic valve from a purely experimental piece of equipment to something which could be produced in considerable numbers on a commercial scale. The three-electrode valve soon began to displace the more clumsy spark apparatus and in the inter-war years, valves consisting partly of metal and partly of glass capable of generating over 100 kw. were designed.

The introduction of the thermionic valve enabled more sensitive receivers to be designed so that high receiving aerials were no longer necessary and use could be made of closed aerials consisting of rectangular loops of wire. The response of these aerials depends on their orientation to the sending station so that the way was clear for the development of radio direction-finding equipment which provides a valuable aid to navigation both by sea and air. It was also found that the thermionic valve provided a convenient means for the generation and

reception of continuous waves, that is for the generation of oscillations of equal amplitude instead of oscillations of decreasing amplitude, as used in the earlier spark systems. Continuous waves are essential in any system of radio-telephony, and as a natural consequence of the introduction of the valve transmitter the advent of broadcasting and the growth of the radio industry came about. It is impossible to transmit speech over very great lengths of submarine cable, so that the introduction of valve transmitters also made possible the development of long-distance radio-telephony and led to the setting up of a telephone service across the Atlantic by the co-operation of the Post Office in this country and the Western Electric Co. in America.

*Short wave lengths*

A revolution in radio communication technique, however, began in 1924. Up to this time it was believed that long waves of the order of 7,000 to 10,000 metres were essential for satisfactory working over long distances, while waves of 250 to 1,500 metres were required for broadcasting and marine purposes. Radio has always attracted keen amateur experimenters, but with the growth of radio communications of all kinds, the Post Office found great difficulty in allocating to them wavelengths upon which they could work without interfering with other services. In the early 1920's the amateurs were allocated wavelengths below 200 metres, mainly because it was considered that these waves would be useless for commercial purposes. The amateurs finding the longer wavelengths of the range allocated to them not very satisfactory, naturally began to experiment on the shorter waves. Soon remarkable results were obtained and amateurs transmitting on a few watts found themselves in communication with their fellows in America, Australia and even New Zealand. In 1924 Marconi organised experiments to investigate the commercial possibilities of short-wave transmission and, in the course of these, daylight communication with Sydney was established on 32 metres. The success of these experiments was so great that in a few years the Marconi Company accepted a contract from the Post Office for the erection of a series of stations working on short-waves of from 16 to 40 metres designed to provide service to the Dominions with a guarantee of reliability previously considered impossible.

The better performance of these stations was also due to the use of 'beam' aerials or reflectors which enable the transmitted energy to be largely concentrated in the direction of the receiving station instead of being radiated equally in all directions. The possibility of using such aerials was foreshadowed by the work of Hertz but it was only with the introduction of short-waves that it became possible to design them in manageable dimensions.

*Radio research*

The practical developments of radio communication which took place during World War I and in the following years had made it clear that there was a number of scientific problems common to all users of radio telegraphy which could best be investigated by a central organisation. To fulfil this need the Radio Research Station was established in 1920 by the Department of Scientific and Industrial Research under the Chairmanship of Sir Henry Jackson. The Board consisted of representatives of the fighting services, the Post Office, the B.B.C., and independent men of science. It immediately began an intensive study of such problems as interference with radio communications by atmospheric disturbances, and the mechanism of the propagation of waves through the ether and its effect on the strength of the signals received.

*Radar*

In all radio services, especially those over long distances, the strength of the signals received was found to vary from season to season and at times from hour to hour. With medium waves, such as those used for broadcasting, distant stations were often inaudible in the daytime but became loud at night, while with much shorter waves the reverse was found to be the case. It was long believed that radio waves reached distant points by reflexion from electrically charged or ionised regions in the upper atmosphere. The existence of such regions had been postulated to explain the phenomena of terrestrial magnetism, but it was not until their existence had been demonstrated beyond doubt by the experiments of Dr. E. V. (now Sir Edward) Appleton at Cambridge on behalf of the Radio Research Board that a detailed study of the upper atmosphere and its effect on propagation became possible. As a result of the technique developed in these experiments it has been found possible to explore the electrical state of the upper atmosphere and to measure, for example, how many free electrons are present in a cubic centimetre of air at, perhaps, a hundred miles above the earth's surface and to show how and why this number varies under the influence of the ultra-violet light of the sun from year to year, from season to season and even from hour to hour. With information obtained in this way it is now possible to forecast with a fair degree of accuracy what wavelength is most suited, at any particular time, for the maintenance of communication between two given stations. The work of the Radio Research Board also explained the surprising errors which were at times encountered in radio direction-finding and showed how they could largely be avoided. When direction-finding started, the possibility of such errors was not suspected.

Thus before 1939 many of the best scientific brains of the country were concentrating on the application of radio, particularly in the form of radio-location or 'radar' as it is now called, for the detection and location of aircraft. Largely as a result of their efforts, a chain of radio-location stations was established round our coast and contributed to our victory in the Battle of Britain. The complete story of the part played by radio in the defeat of the night bomber, in the bomber offensive, in the war at sea and in the invasion of France are outside the scope of this survey. Nor is it possible as yet to forecast the effect which the radio developments of the war years are likely to have on post-war civilian radio, except to say that there is no doubt they will make a profound contribution to the safety of civilian flying and to navigation at sea. It may be well to record, however, two important factors which contributed to our pre-eminence over the enemy in the radar field and did so much to enable this country to withstand a numerically superior enemy in the dark days of the war. The first was that the foundations of radar and its special technique had already been laid in the fundamental scientific work carried out by the Radio Research Board in its study of the upper atmosphere (particularly in the study of pulse technique) and the use of the cathode-ray oscillograph which this work brought in its train. The second was the foundation of a British television industry admirably adapted for the rapid development and production of radar equipments embodying its ideas and closely applied to this technique. Without this close co-operation between science and industry this country might have perished.

*Television*

In much of this fundamental work on the propagation of waves the technique used consists in directing rapid pulses of electrical energy upwards and timing the extremely short intervals which elapse between their transmission and return to the earth's surface after reflexion in the ionosphere, as the electrically conducting portion of the upper atmosphere is now called. The instrument employed is the cathode ray oscillograph in which a pencil of electrons is used to portray the pulses on a fluorescent screen, a distant descendant of the discharge tubes used by Sir William Crookes in his studies on the discharge of electricity in gases and by Sir Joseph Thomson in his work on the electron. By means of this instrument time intervals between electric events can be measured to a millionth of a second, while its electric pencil is nimble enough to scan the image of a moving scene in the small fraction of a second required for television transmission, and to retrace it in black and white on the viewing screen in the receiver.

These references to the cathode ray oscillograph bring us to the last

great radio development in the pre-war years, namely, the start of the B.B.C. television service at the Alexandra Palace in 1937. Between that date and the outbreak of World War II this latest achievement of British science and industry was becoming an unparalleled success and the service was on the point of being extended from London to the provinces.

Although systems of television can be traced back for some sixty years, the practical development of television pictures with good definition has taken place only recently. The earliest proposals, such as that by Nipkow, were based upon mechanical scanning methods and used scanning discs or mirror wheels to enable a light sensitive device to view the picture element by element in rapid succession. These methods are limited as to picture definition by the fact that the speed of the mechanical scanning devices cannot be increased indefinitely and as to sensitivity by the fact that each element of the picture is only effective upon the light sensitive device for a very short time.

Later, Campbell Swinton, appreciating these limitations, proposed a cathode-ray tube system in which scanning was to be performed by a cathode-ray beam to overcome the mechanical limitations and in which a mosaic of minute photocells was to be used in the transmitting cathode-ray tube so as to allow each photocell to view a single picture element all the time and so to accumulate a signal over a longer period. Many years had to pass, however, before the photocells, cathode-ray tubes and valves, which were essential to the practical success of any of these proposals, became available.

Baird's work on the mechanical system began about 1923 and by 1932 he had obtained results which were thought to be of sufficient public interest to justify an experimental broadcast service by the B.B.C. on the medium waveband. The picture provided by this service was of low definition, as it was composed of only 30 lines, and it was found to have little entertainment value. The service was discontinued in 1935.

In the meantime, Electric and Musical Industries Ltd. had been working on the cathode-ray system proposed by Campbell Swinton, and were able to provide a picture of high definition by use of the 'emitron' cathode-ray transmitting tube and a cathode-ray tube receiver and by operating on short wavelengths to allow the increased picture detail to be transmitted. After an experimental period during which the B.B.C. transmitted programmes alternately with Marconi E.M.I. apparatus and with an improved Baird apparatus, the latter was discontinued early in 1937. Thereafter, until it was closed down at the commencement of World War II, the B.B.C. Television Service was continued on the Marconi E.M.I. system, using a 405 line picture, and provided pictures of high definition and entertainment value. The public had

purchased some 20,000 receiving sets, the popularity of television was steadily and definitely growing, and a project was in hand for extending the television service into all the densely populated parts of the country. The possibility of the development of television in this country arose largely from the fact that the licensing system used to finance broadcasting made ample funds available for starting the television service and so gave us a long technical lead over the American broadcasting companies which, while anxious to introduce television, were generally unable to raise funds for doing so by selling broadcasting time to advertisers on account of the small initial audiences which could be reached by the early programmes.

*Broadcasting*

It is now widely realised that broadcasting will play a vitally important part in the post-war world. Many before the outbreak of World War II foresaw its great future, not only as a means of communication but also as a means of education and instruction. In these directions and for the entertainment of the people, broadcasting is already, and will increasingly become, both attractive and useful. Broadcasting by the Ministries of Food, Fuel, Agriculture and many other Government Departments will certainly not cease in time of peace. Indeed, many other new developments such as reconstruction, town-planning and the establishment of new industries will undoubtedly be the subjects of official broadcasts.

Broadcasting is a means of communication, and the publication of news vital for the British Commonwealth and Empire is the justification for making the broadcasting authority of the United Kingdom a public corporation rather than a private undertaking. Characteristically, it was not so at first. The British people have nearly always left pioneering to personal initiative. Broadcasting was at first in the hands of the British Broadcasting Company Ltd., which used General Post Office lines to transmit programmes from one broadcasting station to another but, as one member of the Company wrote in 1924, 'While paying attention to our requirements, the General Post Office does not allow broadcasting to interfere for one moment with the more serious needs of the British public.' Britain watched the United States exploit their commercial possibilities by numberless private companies who used the new device as a means of advertisement. By 1922 the United States 'ether' was a bedlam of warring commercial programmes with no agreed allocation of wave-lengths and no control of either receiving or transmitting sets. In Britain, the General Post Office was already issuing licences both for transmission and receiving and the Postmaster General by 1922 felt able to meet the urgent requests of the radio

industry for a national system. So the British Broadcasting Company was formed with a board appointed by the six chief firms manufacturing wireless, and with practically all the rest as shareholders. Its income was to be in part a share of the licences sold by the G.P.O. and, in part, royalties on wireless apparatus. Its spirit, which lived on long after the Company was merged in the British Broadcasting Corporation, was due to the powerful personality of its first executive, Mr. J. C. W. Reith, now Lord Reith. He it was who largely created British broadcasting and its outlook. It was at first looked on with deep suspicion by the press and no less by those engaged in the various forms of entertainment, but the lusty young organisation grew and prospered and its one-time enemies came to welcome radio fare as something that whetted the public's appetite for more news, more music and first-hand enjoyment of concerts and stage plays or variety shows.

The Company began broadcasting in November 1922. In September 1923 there were 125,000 receiving licences; in January 1927, there were 2,200,000 when the Corporation took over its work and responsibilities and, from the twenty main and relay stations then existing, developed the seven regional stations which before World War II were giving listeners in many parts of the country a wide choice of programmes besides the parallel 'National Programme'. The rapid improvement in transmission and receiving sets made this technically possible. It was not merely a choice of entertainment programmes that the regional stations offered to nearly all listeners. A great extension of the news service became possible. The Corporation arranged its now well-known system of outside broadcasts enabling millions of listeners to hear first-hand descriptions of popular events such as the Derby or the Oxford and Cambridge boat race. These outside broadcasts were greatly extended in course of time and have been carried on throughout World War II, though for security reasons many of them have been recorded and subsequently released instead of coming direct from the scene of action.

The B.B.C. Handbook for 1930 gives the following description of the status and powers of the Corporation: 'The British Broadcasting Corporation is not a Government Department; it is a self-governing Corporation operating under a Royal Charter and a Licence; its activities are limited only by that Charter and Licence; the Postmaster General is responsible to Parliament for the B.B.C.'s observance of these limits, but he does not direct the activities of the B.B.C.; the Bank of England is constituted by Charter, the Royal Academy and other societies have charters, many public services in this country work under Royal Charters. They are not Government Departments, nor is the B.B.C.' The Government nominated the five governors and appointed the director

general. The charter expired automatically in ten years and, in 1937, a new charter was granted for a further ten years with a new 'Licence and Agreement' with the Postmaster General. The Board of Governors was raised from five to seven members.

Before World War II, the licences had increased to over 8 million and, during it, to nearly 10 million, which is believed to be nearly saturation point for this country. In 1939 the radio industry for broadcasting had a turnover of more than £20 millions a year. Something like a million new radio receivers were sold each year and probably over 10 million valves, besides other components. Broadcast receivers have been steadily improved as regards quality of reception and simplicity of control both through the development of new circuits and the evolution of the valve from the simple diodes and triodes to types containing perhaps ten or more electrodes.

During the second decennium of the Corporation, an event occurred that overshadowed previous developments. After years of research and experiment a short-wave transmitting station was completed on 19th December 1932 and Mr. Whitley, Chairman of the Governors and a former Speaker of the House of Commons, spoke to listeners in Australia and New Zealand, and six days later the Empire Service broadcast the first Christmas Day 'link-up', culminating in a personal message by King George V, who said in the course of his speech, 'I take it as a good omen that wireless should have reached its present perfection at a time when the Empire has been linked in closer union, for it offers us immense possibilities to make that union closer still. It may be that our future will lay upon us more than one stern test.'

The B.B.C. broadcasts in nearly 50 languages—to South Africa in Afrikaans; to Canada in French; to the Near East in Arabic, Turkish and Persian; to Latin America in Spanish and Portuguese; to Japan in Japanese; to the Far East and India in Hindustani and other Eastern tongues; and to Europe in all its major languages. Alongside these services are regional programmes in English for the Dominions and the U.S.A., and in parallel with them is the General Forces Programme/General Overseas Service, addressed to all who think of Britain as 'home': this is broadcast continuously throughout the twenty-four hours to every part of the world in turn.

Broadcasting will never replace the printed word or the teacher or the musician or actor, but in its many aspects it does and will increasingly supply an emotional background and an aural and ocular presentation which will greatly reinforce all four and stimulate the appetite for fuller knowledge and enjoyment.

## RAILWAYS

Railways in all countries constitute one of the largest single users of raw materials and the manufactured products of industry. Thus in the U.S.A. 20 per cent of the steel output of the country is in a normal year taken by the railroads in one form or another and the figure for this country in the 1930's was 12 per cent (in value) of the steel produced. The railways are one of the most important users of coal, as might be expected; it is less obvious, though none the less true, that they are very large consumers of the products of other industries, such as textiles. Often too, the precise application of these products in railway service differs considerably from that of the general purchaser. For this reason the railways, as users of industrial products, offer great scope for research in the application of methods and materials to their particular problems. In addition the British railways are almost unique in that they themselves are largely manufacturers of their own locomotives and rolling stock. They are thus interested in research both as manufacturers and as users.

In an industrial research organisation there is a tendency to ignore the potential fields for user research. True, Research Associations usually admit users to membership, but this is not as a rule a strong feature of the Associations' activities. Nevertheless, the railways have sought membership in many of the Associations, and there are, in fact, few whose activities do not, from time to time, interest the railways in their capacity as consumers. Apart from their interest in materials and products as such, the railways are keenly interested in researches on processes such as welding, laundering, prevention of corrosion, and the manufacture of paint and textiles.

It is sometimes said that the railways have been slow in undertaking research, and it is of course true that few of them have so far set up a separate and distinct research department. There are, however, reasons for this, many of them connected with the difficulty of centralising work arising in many different departments and in widely separated parts of the country. Behind an apparent disregard of scientific investigation and study, the history of railways over the past fifty years shows a continuous record of technical development, as distinct from research. But development sometimes appears to take place slowly. This is, briefly, because the railways are now so large and their physical assets so numerous that a desirable change in practice or equipment necessarily takes a long time to mature throughout a whole system. For example, to effect an alteration to every locomotive may take five years, because it is only at intervals that may be as long as five years that a locomotive returns to the main workshops where alterations can be carried out.

Though the effort has until lately and for these reasons been largely decentralised, both physically and personally, the technical progress has in fact been great, and in any case a very large amount of this work, however it is described, must necessarily be field work as distinct from purely laboratory investigation. Nevertheless, the first railway laboratory was opened as long ago as 1864 at Crewe, to be followed later by similar establishments at the main centres of the other companies. For example, the laboratory of the old Midland railway at Derby under Archbutt will long be associated with the study of lubrication problems. At the present day there is a greater tendency towards the concentration of all scientific services into a separate department, and also to take much greater advantage of external research facilities offered by Government research stations, research associations, industrial laboratories and universities. Thus the L.M.S. set up a separate research department at Derby in 1933 at the instigation of Lord Stamp, which includes a metallurgical section dealing with investigations relating to the selection and behaviour of metals and their manipulation by casting, forging, heat-treatment and welding; an engineering section, dealing with research on designs and the performance of engineering details of machines and structures, aerodynamical problems, etc.; a textile section and a paint section. Chemical laboratories are also maintained at Derby, Crewe, Horwich, Glasgow and Stonebridge Park. There is also a physics section which deals with problems of ventilation, acoustics, refrigeration, etc. Railway investigations have been carried out at the National Physical Laboratory on the air resistance of trains; at the Chemical Research Laboratory at Teddington on corrosion of boiler tubes. Work has been done on carriage-riding and on rail joints at Cambridge. The other Companies have not yet followed this lead to the same extent, preferring to leave laboratory and research work under the immediate control of the various departmental officers, but they too have become much more research-minded by joining numerous research associations.

The L.M.S. and L.N.E.R. just before the war were building a joint locomotive testing station at Rugby, while the G.W.R. had for many years possessed such a plant. Similar stationary testing plants had been installed by the Pennsylvania railway in the U.S.A. and by the French railways in order to eliminate the uncontrollable variables inherent in tests conducted on the road. This kind of plant cannot deal with the question of stability or of the combustion process in the firebox, where in some circumstances as much as 30 per cent of unburnt coal passes up the chimney. Investigation of this problem has affected subsequent design and incidentally it has shown that if the locomotive is fired at regular intervals, the coal consumption could in many cases be

reduced by 10 per cent. The difficulties of road testing have been largely removed by mobile testing units such as those constructed by the L.M.S. These units can, by means of electrical generators automatically controlled, vary the load behind the locomotive so as to compensate for changes in gradient or external resistance and thus maintain a constant speed. In this way the results obtained can, it is hoped, be integrated with the results obtained by the stationary plant.

It has only been within fairly recent years that research has been thought of as something separate from, and additional to, normal progressive thinking and experimentation, and if the railways have been slow to adopt a modern layout for research, it is partly because they have felt it unnecessary to adopt a new name for a process that has continued quietly without publicity for many years. As already explained, a great deal of railway research is carried out on the track, in buildings and on locomotives and rolling stock, though much of this work has to be conceived in the laboratory where methods of measurement and analysis are worked out. As regards the permanent way, all companies are closely interested in soil-mechanics research and cooperate with the Building Research Station at Watford in this work. Similar co-operation is at the moment taking place in the development of reinforced concrete as an alternative to timber sleepers. A great deal of research has also been carried out both on the track and, where appropriate, in the laboratory on the resistance to wear and corrosion of the rails. The determination of service stresses in rails and other track components, the welding of rails into longer lengths to reduce the number of joints, the repair of rails and crossings by welding, the hardening of rail-ends to resist end-wear and new and better methods of maintenance by means of what is called measured shovel packing are other subjects that have been investigated.

Some of this work is the indirect result of the work of the Bridge Stress Committee appointed by the Department of Scientific and Industrial Research in 1923 under the chairmanship of the late Sir Alfred Ewing. The findings of the Committee published in 1928 were of great importance industrially, for they enabled bridge designers to calculate far more accurately the effect of what is called 'hammer blow' due to unbalanced vertical forces in the running of a locomotive at high speed and so to improve the design of railway bridges in this country and to compete more successfully for contracts for bridges overseas. The report has led to modifications not only in the design of bridges, but also to improvements in the actual track.

Many of the improvements and developments in rolling stock and locomotives have been the result of prolonged study and experiment. Since World War I there has been a steady increase in locomotive

efficiency as a result of the introduction of larger boilers with higher working pressures and the more general use of superheaters, etc. The performance of the locomotive as a vehicle has also been improved by better springing and balancing. Most companies have experimented to a greater or less degree with streamlining—in most cases after wind-tunnel tests, though only one company has actually installed a wind tunnel of its own. An important aspect of this question is that of preventing the exhaust from the chimney interfering with the driver's vision. Water softening has long been the subject of consideration and all the companies practise it to a greater or less extent.

*Development of the locomotive*

In tracing the development of the steam locomotive, it is usual but misleading to start with the 'Rocket'. This interesting engine did, however, surpass its numerous predecessors because two major developments were incorporated in its design, namely the multitubular boiler and the blast pipe. On these two factors depend the remarkable evaporative power of its relatively small boiler, and it is only within the last quarter of a century that sporadic attempts have been made to adapt any other form of boiler to locomotive work. It is worth noting that the boiler of the 'Rocket' evaporated 5 lb. of water per lb. of coke, whereas the best modern boilers of the same type will evaporate about 8 lb. water per lb. of coal, so that as regards the boiler the story is one of modest but steady progress over a hundred years.

In the actual use of the steam in the cylinders there have been four notable advances. First, there has been a steady increase in steam pressure from around 50 lb. per sq. in. in the days of the 'Rocket' to 250 lb. per sq. in. or more at the present time. Second, the introduction of compounding at the end of the last century enabled the steam to be used much more expansively. Third, the work of Churchward on the G.W.R. reduced the exhaust pressure by improving the design of valve gears and exhaust passages. Fourth, superheating was introduced in the early years of the present century. All these advances tended towards a marked increase in the efficiency of the engine cycle, an efficiency which has risen during the last hundred years from say 5 per cent to 15 per cent, in the case of the most modern examples. Added to the corresponding rise in the boiler efficiency from 50 per cent to 80 per cent, the net outcome in terms of overall thermal efficiency is an increase from say 2½ per cent to 12½ per cent—or fivefold.

The Ewing Report also affected the general design of locomotives, encouraging the increased use of multiple cylinder engines with which designers had been experimenting for some years. The effect of four-cylinder or even six-cylinder engines with cranks at 120 degrees pro-

duced a marked improvement in the condition of the blast in the fire-box, with consequent regular burning approaching the continuous pull on the fire caused by a fan. The steady draught is far more efficient. But the multiple cylinder engine also had another great advantage the importance of which was not realised until the Ewing Report appeared. The more even turning movements in the multiple cylinder engine enabled a great reduction to be made in the balance weights on the driving wheels. The engine is thus much lighter on the road, and the hammer blows are reduced so that both rails and tyres last longer. There would have been great developments in these directions but for the outbreak of war, though in any case the introduction of radical improvements on a large scale would have taken time before all engines could have been dealt with.

Locomotive engineers have no cause to be ashamed of the progress made in efficiency, but the advance in power and weight has been even more striking abroad, particularly in America, where size and weight are much less restricted by the physical limitations set by tunnels, bridges, etc. The tractive effort of the 'Rocket' was 800 lb., that of the 'Royal Scot' is 33,000 lb., that of the 'Coronation' 40,000 lb., while the largest American engines can exert a tractive effort of no less than 150,000 lb. The weight of engine and tender has, similarly, risen from 7½ tons in the case of the 'Rocket' to 164 tons for the 'Coronation' and 400 tons or more for the largest articulated engines abroad. At the famous Rainhill trials, the 'Rocket' drew a load of 13 tons on the level at 29 m.p.h.; the 'Coronation' takes 500 tons from London to Glasgow at over 50 m.p.h., whilst the American giants haul passenger trains of 1,500 tons and freight trains of 5,000 tons and upwards.

In the wider question of alternative forms of power, the railways have experimented with turbine locomotives, diesel power (particularly for shunting) and pulverised fuel firing, while the question of electrification is constantly receiving expert technical consideration, though these subjects go beyond what would normally be called research. From time to time attempts have been made to introduce ultra high pressure turbine or condensing locomotives in an effort to improve efficiency or to meet special conditions, but the increased weight and complication have stood in the way of any general adoption of these types for locomotive purposes, notwithstanding their outstanding success in power station and marine practice.

### *Electric traction*

Electric traction with its even drive avoids the hammer blows of the steam locomotive but may cause a periodic lateral pressure which leads to wear of the rail head, particularly if electric locomotives instead of

multiple units are employed. This has led to the laying of harder steel rails by the London Passenger Transport Board for trams.

Before the war electric traction had been introduced for passenger traffic on 2,387 miles of the main line companies, mostly in the surburban areas of London, Manchester, Mersey-side and Tyne-side, but also on the lines linking London and the South Coast towns between Hastings and Portsmouth. A heavy electric locomotive is now hauling freight trains in the South and one has been built for the heavy gradients between Sheffield and Manchester though the electrification of this line has not yet been completed. But the further extension of electric traction is an economic question and has to be compared with the results of the latest steam engine design and of diesel traction.

### *Passenger vehicles*

What may be termed the amenities of passenger travel have been subjected to much theoretical and practical research, e.g. the smooth riding of passenger vehicles, which depends on the contour of the tyres and on the springing system; better methods of heating, ventilation and lighting; and the reduction of noise. In particular the London Passenger Transport Board has conducted a series of experiments for the reduction of noise in the tunnels of their system, one factor in which has been the introduction of longer lengths of rail.

### *Paint*

The painting of rolling stock has always been the subject of much research. This is a difficult problem because the claims of reduced painting schedules have had to be balanced against adequate resistance to cleaning solutions. Nevertheless, the old 17 coat schedule is a thing of the past and research on new materials and new methods of application has reduced the number of coats to half a dozen, with a great saving in time and cost, and little loss in resistance to acid and alkali.

### *Signalling*

Railway signalling, on which not only safety but speed of operation depend, particularly under adverse conditions, underwent much modernisation and development in the inter-war period. A wide introduction of colour light signals was made to improve conditions in fog and these are identical by day and night. Experiments on various forms of automatic signalling have been made to cause the automatic application of brakes and to afford an audible warning to the driver. Research has also been undertaken on fog forecasting and dissipation.

*Other problems*

Many ancillary problems are the subject of research from time to time; for example, improvements in the manufacture of wagon sheets, vehicles for refrigerated service, reduction of noise in buildings (hotels, offices, etc.). In all these instances research methods are important for obtaining proper assessments of existing and improved conditions, which otherwise can only be judged by mere impression and opinion. An important function of a research organisation for a railway is to assist the other departments by offering advice on subjects which are outside the ordinary run of their experience and by bringing to their notice the results of scientific studies which have a bearing on their work. At least one company publishes a monthly review of scientific and technical literature for internal circulation.

## SHIPPING AND MARINE NAVIGATION

Shipping is for this country largely, even predominantly, an international means of communication which as the population has increased has become vital to its subsistence. That is why a strong Navy, able to maintain the freedom of the seas and to protect the country's mercantile marine, is essential for its independence and liberty. Indeed national shipping was in the first instance purely military—founded by Alfred the Great to protect the country from invasion. Later, as overseas trade grew, the mercantile marine came to outnumber the navy which in times of international crisis had to depend largely on the merchant ship for the reinforcement of its fleets.

The international duties of most of our mercantile marine have naturally led to international agreements for the improvement in the design and equipment of ships in the interest of safety for sailors, passengers and cargoes, for in the absence of minimum standards in these matters our overseas trade would inevitably suffer. Accordingly the greater safety of transport by sea has been secured by international conventions made operative by national legislation, and on those sea lanes which are used largely by the ships of other countries agreements have been made with a view to avoiding cut-throat competition. The well-known Atlantic Conference is an example.

A factor of fundamental importance for the safety of seagoing ships is the determination of the load-line. As early as 1873, Lloyd's Register had made the marking of a load-line compulsory for the classification of vessels of the Awning Deck type, and in 1876 a Merchant Shipping Act compelled owners of all foreign-going and coasting ships to have a load-line marked before leaving British ports. No rules were formulated,

however, as to how the position of this load-line mark was to be determined. In 1882 provisional Tables of Freeboard applicable to all classes of vessels were published by Lloyd's Register and voluntarily adopted by a large number of ship owners. These tables, somewhat modified, formed the basis of the later compulsory legal requirements, introduced in the Merchant Shipping Act of 1890 and amended in 1906 and 1932.

The principal matters dealt with in the 1932 Merchant Shipping (Safety and Load Line Conventions) Act—the basis of the Board of Trade's Rules and Instructions—are: (*a*) construction and survey of passenger ships, their sub-division and pumping arrangements, and stability tests for new ships; (*b*) life-saving appliances with instructions as to the construction, stowage, equipment and manning of lifeboats and other life-saving appliances, the mustering of passengers and crew in the event of disaster, and boat drills; (*c*) fire-detecting and fire-fighting appliances in passenger ships; (*d*) wireless telegraphy regulations—these impose the obligation to carry an effective wireless installation with a qualified operator on all cargo ships of 1,600 tons gross and upwards and on all passenger ships irrespective of size; (*e*) distress signals; (*f*) safety of navigation—the transmission of information regarding the presence of storms, ice, derelicts and other dangers to navigation; (*g*) amended load-line regulations with more efficient conditions of freeboard assignment—the new regulations introduced *inter alia* freeboard tables for tankers and vessels carrying timber deck-cargoes.

This legislation and the Board of Trade rules were the result of international conventions in 1929 and 1930 which were unanimously signed by the representatives of twenty-seven Governments. The Board of Trade rules are, of course, minimum standards and many shipowners have exceeded them. After war broke out in 1939 further rules and regulations were issued affecting life-saving appliances, wireless and fire appliances, in the preparation of which the Technical Committee of the Chamber of Shipping and the Joint Wireless Committee have co-operated with the Ministry. The latter committee has given much attention to future means of improving and developing wireless in lifeboats and meantime to increase the effectiveness of existing sets.

Individual shipping firms have greatly improved the methods of ventilation in passenger ships, so that the comfort of internal cabins is as great as, and even superior to, that of cabins with port-holes, while the efficiency of fishing and whaling fleets has been increased by the adoption of large factory ships which accompany the fishing or whaling vessels and deal more promptly and effectively with their catches than similar establishments ashore.

As some indication of the extent to which Great Britain and Ireland

have provided the mercantile marine of the world in recent years the following statistics compiled from Lloyd's Register of Shipping are illustrative:

GROSS TONNAGE, IN THOUSAND TONS, OF MERCHANT VESSELS LAUNCHED

| | *Great Britain and Ireland* | | | *Abroad* | | |
|---|---|---|---|---|---|---|
| | *Steamers and Motor-ships* | *Sailing Vessels and Barges* | *Total* | *Steamers and Motor-ships* | *Sailing Vessels and Barges* | *Total* |
| 1905 | 1,605 | 18 | 1,623 | 801 | 90 | 892 |
| 1909 | 973 | 18 | 991 | 564 | 46 | 611 |
| 1913 | 1,920 | 12 | 1,932 | 1,269 | 132 | 1,401 |
| 1920 | 2,040 | 16 | 2,056 | 3,703 | 103 | 3,806 |
| 1930 | 1,472 | 7 | 1,479 | 1,364 | 47 | 1,411 |
| 1935 | 497 | 2 | 499 | 794 | 9 | 803 |
| 1938 | 1,026 | 4 | 1,030 | 1,950 | 53 | 2,003 |

### *Marine navigation*

Modern navigation by sea may be said to date from the making of the quadrant by Godfrey of Philadelphia in 1730 and by Hadley of London in 1731, anticipated in an unpublished description by Sir Isaac Newton. When in 1736 John Harrison, a young Yorkshire carpenter, made his first chronometer as a 'more certain and practicable method of ascertaining longitude than any yet in practice', for which a prize of £20,000* had been offered by Act of Parliament, these two instruments made navigation possible in its modern sense. The quadrant, now sextant, replaced the backstaff and cross-staff which, with the compass and such charts as existed, were the chief navigational instruments prior to 1730. The chronometer with Harrison's principle of compensation made it possible to determine Greenwich time with great accuracy, no matter in what part of the world the navigator may be; this, by comparison with the local time, determined by aid of the sextant, gives the longitude. Since then the sextant has been greatly improved, both in accuracy and also in the direction of observing stars at dusk and dawn. The introduction of the bubble horizon has enabled the navigator to observe

* It was not until 1773 and after a further Act of Parliament that the award was finally made, 45 years after the beginning of his experiments and only 3 years before his death. Harrison was awarded the Copley Medal of the Royal Society for his work on the chronometer in 1749.

altitudes at sea and in the air when the horizon is not visible, and the incorporation of mechanical averaging and integrating gear has much increased its usefulness.

*Compasses.* The short needle compass with slow periods of swing to improve the accuracy of 'dead reckoning', as the keeping account of a ship's position by compass and log is termed, was originally invented by Kelvin in 1876 and his dry-card compass became the standard instrument of the British navy. The dry-card compass has been replaced largely by the liquid compass which is more responsive and steady in bad weather and under vibration. There is also the gyro compass which does not depend for its working on the earth's magnetic field but on gravitation and the earth's rotation. Thus it is not affected by the masses of iron and steel used in the construction of modern ships. It was primarily the work of the Sperry Company of the U.S.A.

*Logs.* The Cherub or Taffrail log for recording the distance run was introduced in 1878 to replace the handlog. It recorded the revolutions of a small screw towed by the ship. These earlier towed logs were superseded by the Walker log which records distance travelled and, by its towing resistance, the speed of the ship. Other distance meters include the Chernikieff log which operates by a measuring propeller in the sea below the vessel connected with a recording apparatus inside the hull. Another is the *pitometer* log, used in the British navy and introduced in the 1920's. The instrument, based on the principle of a *pitot** tube, is connected to the bottom of the ship with a recording apparatus in the hull. Speed meters have also been devised with electrical transmission to the bridge of the ship so that control can be exercised with a view to timing arrival in port and to reducing fuel consumption.

*Other navigational aids.* The leader cable system is another aid. Electric signals can be transmitted from submarine cables laid in harbourages to be picked up by the ship when passing through places of danger. The greatest length of such cables is about 40 miles at a depth of 30 fathoms. A cable of this kind was laid at Portsmouth some years ago.

With the advent of wireless a new form of assistance became available. The exact determination of a ship's position by astronomical observations depends in large measure on the accuracy of the ship's chronometers, but by means of wireless the correct time can be ascertained in most parts of the ocean. By 1925 there were over 50 stations working on different wavelengths transmitting the time daily. Wireless direction-finding is another aid. The instrument enables a ship to take bearings

* A *pitot* tube, so named from Henri Pitot who devised it in 1730, consists essentially of a double tube, the open end of one tube facing the stream and the other being at right angles to it and projecting into the hull. The pressure difference is recorded and is a measure of the ship's speed.

on a wireless transmitting station and to fix its position with accuracy at times when other navigational aids fail, e.g. in thick weather. The direction can either be transmitted from shore and picked up by the ship or a direction-finder can be used in the ship to make contact with the shore or with another ship. Collisions in fog can thus be avoided. The 'radio feeler' is yet another aid; in this case a radio beam, centred fore and aft of the line of the ship, describes an arc of 45 degrees about the direction of a ship's travel and if the beam is intercepted by any object in its path, a loud-speaker announces the fact on the bridge of the ship. Objects about 4 miles away can be detected.

With the introduction of radar (see p. 213), a further important navigational aid became available of which great use is made.

Echo sounding has replaced the old method of lead and wire sounding. By this acoustical method of recording the interval between the emission of a sonic signal from the ship and its echo reflexion from the bottom of the ocean very great depths can be gauged and the presence of wrecks and other large bodies such as whales and submerged icebergs can be detected. A further advance was made when supersonic echo sounders became available. These are of two kinds, one in which the supersonic waves are generated by applying alternating electrical potentials of suitable frequency to quartz crystals, the other in which these are applied to nickel laminations, utilising the phenomenon of magneto-striction. This type of echo sounder is now very widely used and is of great value to the navigator.

A very important development was the initiation of the *Nautical Almanac* published by the Commissioners of Longitude in 1767 at the instance of Nevil Maskelyne when Astronomer Royal. The *Nautical Almanac*, which is now issued annually in advance by a special branch of the Royal Observatory, Greenwich, gives all the astronomical information with regard to the sun, moon, planets and stars required for navigational purposes; the original almanac having been enlarged to serve observatory purposes. An abridged edition for the use of seamen was introduced in 1914. In 1937 another edition, arranged on different lines to reduce the navigator's work to a minimum, was introduced for air navigation and is called the *Air Almanac*. The original plan of the almanac has been copied by other countries. Although the almanacs of different countries vary slightly, the fundamental calculations on which they are based are the same and are produced by international co-operation.

The charting of the ocean has greatly assisted navigation and the formation of the Admiralty Hydrographic Office in 1795 marked an important step in this direction. The charts compiled for the use of the East India Company furnished a nucleus and the Admiralty charts had

grown in number to 962 by 1830. Since then nearly every part of the inhabited globe has been charted for the use of the seafaring community of the world, together with information on the closely allied subjects of tides, compass adjustment and ocean meteorology. As the size and speed of ships increased added importance was given to all these aids to navigation and the world owes much of its safety at sea to Great Britain. Shipbuilding is dealt with in chapter 25.

## WATERWAYS, ROADS AND ROAD TRANSPORT

### *Waterways*

'The subjects of Queen Anne had great ships in which they sent heavy goods with ease to America and to India, but inside their own island they were still despatching sacks of coal and hardware strapped to the sides of pack-horses, because wheeled traffic would have stuck in the mud and broken in the ruts of English roads wherever their route crossed a pocket of clay.' (G. M. Trevelyan, *English Social History*, p. 382.) Consequently the development of our waterways took precedence in time over our roads and, save for the remains of the old Roman roads which had been neglected for centuries and in any case were military, not commercial in purpose, they were entirely inadequate as a means of communication between cities that had grown up on the rivers and between the mines, quarries or fields and pastures which were producing more and more of the basic necessaries of life for town or country. So rivers were deepened and locks made. Food, timber and other heavy cargo floated down the Thames and its tributaries to London, and coal from the north and goods from abroad were towed up-stream. After the Union with Scotland, Great Britain was the largest free-trade area in Europe, and this further stimulated the passage of agricultural produce in particular in exchange for other goods.

The second half of the 18th century saw a further extension of the waterways by the first building of canals by 'the father of inland navigation', the Duke of Bridgwater, with the assistance of his artisan engineer, James Brindley. The Duke was a colliery owner and to link up his mines with Manchester, he devoted his wealth and his influence in Parliament. This was the beginning of a movement that, in the next fifty years, gave England a network of canals which ultimately reached a total of 2,500 miles, piercing the hills by tunnels and crossing the valleys by aqueduct. But, after fifty years of prosperity, the profits earned by the canals were wiped out by the rapidly growing railway system, and many of the canal companies were bought up by the railways.

*Road improvement*

Meantime for more than two centuries up to 1800 the roads were in the control of Turnpike Trusts who, from ignorance of the principles of road construction, were incapable of keeping them in repair under the increased wheeled traffic. At the beginning of the 19th century there were 1,100 Trusts in charge of 29,000 miles of road. Then began the first application of engineering science to the problem. Telford, McAdam and other engineers employed by the Trustees for the first time applied the following principles: (1) careful preparation of the road bed; (2) the use of hard stone, even if none was available locally; (3) careful selection of the stone to ensure a closely-knit, interlocking body of material; (4) a well-cambered, dense surface to throw off rain water; (5) adequate attention to drainage. By the middle of the century the fast four-horse passenger coaches had in the result reached their zenith but thereafter until the close of the century road transport, under the impact of the new railways, declined to a 'local' status and the turnpikes were taken over by local government. Then came the present century with its motor traffic and the urgent need to improve existing highways to carry its rapid increase and high speed. In 1919 there were 650,000 vehicles on the roads, including motor cycles. At the beginning of World War II the number was 3,000,000 and was still rising. Motor transport ceased to be mainly local but became largely inter-regional and road maintenance was no longer a parochial affair. After World War I the Ministry of Transport was established to take over the duties of the Road Board of 1909 and a Road Fund was inaugurated to assist local authorities. Next the Ministry took over trunk roads from them and a long term programme for their improvement was initiated.

*Modern research*

So was reached the first systematic and centralised approach of science and experiment to the problems of our roads. In 1930 a small experimental station was built at Harmondsworth, Middlesex, by the Ministry of Transport which called in local authorities, private industry and the Department of Scientific and Industrial Research to assist in the work. In 1933 on the advice of the Parliamentary Select Committee on National Expenditure, the Harmondsworth station was transferred to D.S.I.R. and became the Road Research Laboratory (see p. 287).

The problems created by modern traffic have been mainly concerned with: (*a*) traffic flow (i.e. getting the right shape of 'channel' and the right form of intersection); (*b*) strength and durability; (*c*) surface characteristics (evenness combined with non-slipperiness); (*d*) traffic

control; (*e*) street and vehicle lighting. Most of these problems have been tackled with two objectives: safety and economy, with a third objective (comfort) to some extent in mind. Much of the experimental work has been concerned with economy, but road safety has been the object of much deliberation, for the most part by the Ministry of Transport. It is now being recognised as an important subject for research. Many improvements in road technique are the result of practical experience but in recent years organised research has played an increasing part. The following are some of the main advances.

(*a*) *Traffic flow*. Dual carriageways have been developed for main road traffic. Standard lane-widths have been fixed with the provision of extra width on curves. Banking on curves has been to some extent standardised; so have cambers. Types of junction to suit different traffic densities have been devised. They are in descending order, the fly-over, the roundabout and the 'staggered' crossing. But there still remains the need for quantitative observations and measurements leading to the establishment of rules to govern design.

(*b*) *Strength and durability*. The era began with ordinary 'waterbound' macadam roads and indifferent foundations. The first problem was surface disintegration and the dust nuisance. This was solved by the use of tar dressings covered with small stones, but as traffic increased, this treatment was not enough. The tar (or asphaltic bitumen) was accordingly mixed with stone to make a surface several inches thick. Foundations also required strengthening, and concrete foundations were next introduced—at first covered with bituminous surfacing but later used as a combined foundation and surfacing. A great deal of work has been put into improving the quality of bituminous and concrete roads. Surface dressings now last 3–5 years instead of 1–2; tar and asphalt surfacings last 10–20 years instead of 3–8; concrete, probably 25–30 years instead of about 10. Special thin bituminous surfacings (carpets) have recently been introduced. Other recent developments include a fuller understanding of the function of the soil in supporting loads; better embankment construction; better soil drainage; and the use of 'stabilised' soil as a material of construction. Great strides have been made in the use of machinery in road construction. Earth-moving machinery (mechanical diggers, bull-dozers, scrapers, graders, trenchers, etc.) is now employed, and mechanised screens are used for grading stone as well as mixers for bituminous materials and concrete.

(*c*) *Surface characteristics*. Up to about 1920, the surface quality of roads was poor. Surfaces were lumpy, partly because they were laid badly and partly because the materials corrugated or broke up under traffic and traffic made them slippery. Much has been done to put things right. The improved materials are not so easily disturbed by traffic

and improved methods of laying (including 'finishing' machines) ensure initial evenness. Troubles at joints in concrete roads have been largely cured. But a still higher standard of surface-evenness is required. Studies of the contours of roads are being made in greater detail with the aid of 'profilometers' and other special apparatus. The causes of slipperiness are now fairly well understood and the physical laws connecting surface texture and slipperiness have been established, so that complaints of slippery roads are now far less frequent. The tone and colour of surfaces have received some attention with the idea of improving visibility and reducing glare. The relation between surface texture and wear of tyres is also being studied.

(*d*) *Traffic control.* By road signs, automatic signals and surface markings. Public highways carry mixed traffic ranging from the slow-moving pedestrian to the high-powered car or lorry. Physical segregation is the only complete solution of the difficulties involved, but much has been done without so radical a cure. Direction signs have been standardised and lowered in position so as to be visible with headlamps; advance direction signs help the motorist to focus his attention on the road. The 'Major Road Ahead' warning sign, by establishing priority, has been very helpful. Great ingenuity has been displayed by the electrical industries in perfecting automatic signals (traffic-actuated, time cycle and pedestrian-operated). Surface markings (white lines) are being actively studied and have already made an important contribution to safety, and so have pedestrian crossings. One-way streets in towns help greatly in easing traffic flow.

(*e*) *Street and vehicle lighting.* In street lighting the problem has been to get uniform shadowless and glareless lighting on a continuous strip of road which is illuminated by intermittent sources of light and has a surface from which the reflexions vary with the weather and with the character of the surface. In other words, the problem involves the road surface as well as the lighting unit and is consequently very complex. As yet, it has been only partially solved. Big advances in lighting have been made by ingenious designs for reflectors as well as by the use of gas-discharge lamps, but no special achievement has been made in vehicle headlamps though it is a promising subject for research. Yet of all the problems of modern traffic the most urgent is still the question of safety, the solution of which affects not only the design of roads and crossings and their illumination, but also, as suggested elsewhere (p. 11), the design of the vehicles themselves.

### *Public road transport*

The growth of transport by road, both for passengers and goods, has been phenomenal in the last twenty years. The sale of commercial

vehicles more than doubled between 1924 and 1935 and the competition of private firms engaged in road transport greatly affected the railway companies, which contend that the transport firms make no adequate contribution to the upkeep and extension of the national road system while the railways have to bear the whole cost involved in the building and maintenance of their railroads. Moreover they contribute to the cost of the ordinary roads of the country and are subject to the Railway Tribunal in the charges they make for carrying goods of all kinds. On the other hand the motor licence duties in the years just prior to World War II amounted to about half the cost of road maintenance improvements and new construction, without taking into account the petrol tax which yielded considerably more revenue than the licence duties. Since the establishment of the London Passenger Transport Board which controls the passengers both by road and rail over an area of 30 miles radius the cut-throat competition of the two means of travelling has ceased and similar results have been gradually obtained by the railways securing a controlling interest in various provincial motor omnibus companies.

# CHAPTER 29

# FOOD PRESERVATION

Food investigation has been one of the major concerns of the Department of Scientific and Industrial Research; and the following is a brief account of the work of the stations concerned with it. As will be seen, the work is not only of national importance but of Empire significance.

### *Meat*

Early work in the Department's laboratories and elsewhere indicated that preservation of quality in frozen animal tissues was largely a function of the rate of freezing, but the rates required for complete preservation were so high as to be unobtainable in commercial practice with so large a unit as a quarter of beef. The 'quick freezing' of smaller cuts of meat was subsequently developed on a large scale in the United States, but even with small cuts it is difficult to freeze at the rate theoretically desirable. Research in this country has indicated that under practical conditions the advantage of 'quick freezing' is represented more especially by a diminution in the quantity of drip on thawing, which makes the quick frozen product more satisfactory to handle and more attractive to the purchaser. In palatability little advantage can be demonstrated.

Chilled beef has a higher market value than frozen beef in carcase form, but the period of preservation is limited. This country could import beef in chilled form from Argentina where the voyage period is only three or four weeks, but supplies from Australia and New Zealand had to be frozen, and commanded a lower price. There were two alternatives—to seek improvement in the quality of frozen beef, by new methods of freezing and thawing, or to seek some means of increasing the storage 'life' of chilled beef to enable a voyage of double the previous length to be made.

Success was eventually achieved along the second line. The essential discovery was that moderate concentrations of carbon dioxide would inhibit the growth of micro-organisms sufficiently to enable chilled beef to be marketed free from mould growth and without serious effect on the external appearance (what is known as 'bloom' in the trade) of the carcases. Higher concentrations of this gas, i.e. 20 per cent or above, produce an unpleasant discolouration of the superficial tissues which entails a considerable loss in market value. The discovery was quickly

followed up in commercial practice. In the years between 1935 and 1939 increasing quantities of beef were being brought to this country from Australia and New Zealand in chilled 'gas' storage, and these distant Dominions were enabled to compete on more equal terms with countries geographically nearer.

Work on the curing as distinct from the transport of meat has been largely in the nature of a consolidation of existing good practice rather than of spectacular advances in technique. Investigation of the role played by nitrate, nitrite, and bacteria in the salt curing of bacon have led to important changes in that process.

*Eggs*

Important work has been done on the gas storage of eggs. Eggs in shell are usually preserved by cold storage alone, but a process of preservation in a high concentration of carbon dioxide (80 per cent to 100 per cent) at low temperatures, was also known and practised. Such high concentrations affect the quality of the egg, causing for example, some shrinkage of the thick white and a thinning of the white as a whole. Storage in air can be quite satisfactory from a micro-organism point of view so long as the air is slightly dry and it was found that the introduction of a small amount of carbon dioxide, of the order of 2½ per cent at 32° F., maintains the natural condition of the egg white. If this percentage of carbon dioxide is combined with an accurate control of humidity and temperature, an almost ideal storage condition for shell eggs can be produced. Here again the results of research have an important bearing on the practice of handling eggs in exporting countries previous to shipment.

*Fish*

As a result of the establishment of the station at Torry, Aberdeen, in 1929, work was initiated on the problems of the preservation and transport of fish. Organisations of a similar kind in Germany, Norway, Canada and the U.S.A. have also been engaged in this field of study, but the conditions peculiar to this country have been given special attention at Torry. The early work on the handling and stowage of white fish at sea, conducted on board commercial vessels, was a first attempt to introduce scientific methods into the fishing industry. It was found that when greater care was paid to cleanliness in the handling of the fish, i.e. in washing to remove slime, blood and pieces of gut, to the use of metal fittings, etc., and to proper stowage in ice on board ship, the normal period of freshness could be considerably increased. As a result of this work, definite improvement in the handling and stowage of fish on commercial vessels has occurred in recent years.

The introduction of the steam trawler, with improvements in the catching power and in the use of ice, in time led to the overfishing of the nearer grounds, and consequently to the extension of fishing to ever more distant waters. An increasing proportion of long voyages exceeds the limits of the preservative capacity of ice and much of the fish landed here from far distant grounds is definitely stale.

The failure of ice to preserve fish fresh, for periods longer than 10 to 12 days, led to experiments on rapid freezing, followed by storage at temperatures from 0° to −20° F. The most favoured methods of freezing appear at present to be either contact-freezing between plates or freezing in rapidly moving air, although in promising commercial experiments carried out by European countries on cold storage of fish at sea in vessels ranging in size from factory ships to large trawlers, brine freezing was the method adopted. Fish frozen by such methods and properly stored, keep in a 'fresh' condition for six months or more. The application of these freezing methods at sea affords one solution at least to the problem of how to bring white fish from the distant grounds and land them in first class condition at the fishing ports.

Moreover, by the use of freezing and cold storage it should now be possible to even out supplies and to provide high quality fish at all seasons of the year. This is particularly applicable to the herring, caught in large quantities almost exclusively during the summer and autumn months, which thus could be supplied throughout the whole year, not only as fresh fish but also for smoke curing and canning.

The salting of white fish and the pickling of herrings have been traditional practices for a long time and more fish are preserved throughout the world by salting than by any other method. But the public liking for salted fish in the more developed countries, at least, has diminished. Experiments have shown that micro-organisms play a considerable role in the development of the flavour of salt herrings and that a reduction in the strength of the pickling brine below a certain level does not permit the development of the typical 'salt-cured' flavour. A limit to the 'lightness' of cure has been determined to meet the required standards of taste and secure adequate curing. The salting of white fish, their drying and conditions of storage have been the subject of study in Canada in recent years; and the storage of 'wet' stacked salt fish in this country has been studied at Torry, especially as regards deterioration due to bacteria carried in the curing salts. In particular it is found that chill storage at about 40° F. or lower, prevents spoilage for many months and the trade is now beginning to use these recommended storage conditions.

Smoke curing, another traditional practice, has also been investigated. Experiments have shown that the degree of preservation resulting from the process is due to a combination of smoke, salt and drying and that

a deficiency in any of these, results in a product of inferior keeping quality. In traditional practice control is inadequate, but the experiments on the subject at Torry have led to the design and construction of a smoking kiln in which the necessary controls can be exercised and at the same time a saving in labour achieved.

*Fruit and vegetables*

Work of a particularly successful nature has been done on the 'gas'-storage of fruit in this country. For many varieties of English apples cold storage in air is not really successful because they develop a functional disease known as low-temperature breakdown when kept for considerable periods at temperatures just above freezing point. Sometimes the cold-stored apple may appear to be in perfect condition when first removed from the store, but breakdown may develop rapidly during marketing and distribution. Investigation showed that the trouble could be avoided by keeping the temperature of storage higher and by controlling the carbon dioxide and oxygen content of the storage atmosphere in order to retard ripening. In an atmosphere containing more carbon dioxide and much less oxygen than normal air, the life of the fruit can be greatly prolonged and its green ground colour and firmness retained to a remarkable degree. Accurate temperature control is, of course, equally important.

Fruit-growers and cold storage engineers were not slow to take advantage of these discoveries, and as a result the Bramley's Seedling variety—the most widely-grown cooking apple in the country—can now be commercially stored up to May or even June. In 1930, the total capacity for the refrigerated gas-storage of fruit in this country was no more than 27,200 cubic feet, but by 1936 it had risen to 2,813,000 cubic feet. In fact, refrigerated gas-storage has now widely replaced cold storage in air. The field has been sufficiently explored to prescribe with confidence the correct storage conditions (and pre-storage treatment) for apples, pears and plums grown in Great Britain, based on a detailed study of the factors of climate, soil, cultivation, manuring, orchard sanitation, type of root stock and methods of gathering and grading.

Storage and transport from overseas set a rather different problem. The cause of 'brown heart' in apples was identified in the early days of the Food Investigation Board. Many consignments of apples from Australia and New Zealand had suffered damage from this cause: the symptom was a breakdown and browning of the internal flesh of the apple, sometimes resembling the 'low-temperature breakdown' already referred to, but the cause was different, namely an excessive accumulation in the holds of the carrying vessels of the carbon dioxide generated by the apples themselves in their respiration. In crude terminology, the

apple was suffocated by its own breathing. Laboratory experiments and shipboard surveys both assisted in determining the necessary conditions of ventilation of the ships' holds, and with such knowledge the trouble has been very largely overcome. It is now established practice to record both temperatures and carbon dioxide percentages in the holds during a voyage, and to control the conditions accordingly. The application of correct ripening conditions for imported varieties of pears and plums has also been made possible by investigations conducted at the laboratory in Covent Garden, and this has resulted in a considerable reduction in wastage not only of fruit but of vegetables.

*Dehydrated foods*

The emergencies of war have led to a wide extension of interest in dehydration as a method of preserving foods and of reducing bulk for transport. Some attention to these problems had already been given before World War II in the Department's programme of food investigation, and in the last few years striking progress has been made.

Research has had two main aims, the improvement of quality and the improvement of stability in storage. Quality, which includes flavour and palatability, nutritive value, ease of re-constitution and so forth, depends on the choice of suitable material for drying, and on pre-treatments, such as the 'scalding' of vegetables, as well as on the maintenance of suitable temperatures and other physical conditions during the drying process. Research has therefore covered a wide field ranging from the biochemistry of the material to the engineering details of dryer design. Deterioration in storage is also governed in part by pre-treatment; for example by the preliminary heat treatment designed to inactivate enzymes, and the deterioration due to oxidative changes can be largely avoided by suitable methods of packing. Special attention has been given to 'gas-packing' in sealed tins from which the air is removed and replaced by nitrogen or other inert gas, and to the method of compressing into blocks whereby the access of air is minimised.

Compression is also an important factor in reducing bulk for emergency transport; and an important auxiliary line of research has been the production of special compressed dehydrated foods, and mixtures of foods, suited for use as emergency rations, and the investigation of their storage properties. Particular attention has been devoted to the dehydration of vegetables—potatoes, carrots, cabbage—the production of which for Service needs has now reached a considerable scale in this country. Methods for the dehydration of meat, in the form of mince, have been worked out in detail in the laboratory and on a pilot-plant scale, and equipment for large-scale production has been set up in overseas countries as an insurance against the risk of shipping losses, which

at one stage of World War II represented a threat to our normal imports of meat in refrigerated form. Quality in dried eggs has been intensively studied, and important advances have been made in the preparation and storage of dried milk, in collaboration with the Agricultural Research Council.

*Food infestation by insects*

Foods of various kinds, both raw and processed, are subject to infestation by insects and by mites. It is difficult to assess in precise terms the losses caused by infestation. They may be direct losses as when wheat, maize or millet is completely hollowed out by the insects and rendered worthless, or they may be indirect losses as when goods such as dried fruit (sultanas and dates for example) are rendered unsaleable because of the presence of caterpillars in them. In general the food manufacturing industries are more affected by indirect than by direct losses. The occurrence of one caterpillar in an almond ornamenting a cake or among high class chocolates in a presentation box is a much more serious trade problem than the occurrence of many caterpillars in cocoa beans awaiting shipment at Takoradi.

Infestation is always aggravated by accumulation of stocks and prolongation of storage. It is always marked when there is a glut on the market or when, as in war time, stocks of grain and other foodstuffs are built up in reserve. It is most serious in warm countries and in grains, such as wheat, rice and millet; losses have been recorded amounting to 20 per cent in weight during a few months' storage. It has recently been stated that in French North Africa the loss in potatoes in store caused by the caterpillar of the 'Tuber moth' has exceeded 30 per cent within three months of harvesting.

Indirect loss too is often serious. During 1930–1935, the Australian Dried Fruits Board spent in round figures £30,000 in the control of the moth *Plodia interpunctella*; in 1939 the saving effected as a result of the control measures devised had reached a value of £150,000. During World War I the Royal Society set up, at the request of the Board (now Ministry) of Agriculture, a special committee—The Royal Society Grain Pests (War) Committee—to advise on the protection of grain. It published ten reports and in its last report recommended the continuance of its work under Government aegis. The then recently established Department of Scientific and Industrial Research was proposed as a suitable body to foster this work, but no action was taken.

In 1927 the Entomology Department of the Imperial College began in the warehouses of the London docks an investigation of the occurrence of various insects in various commodities. The commodity most obviously affected was cocoa and in 1928 the College proposed to the

Empire Marketing Board a fuller investigation of the infestation of cocoa in store in London. The E.M.B. approved a grant to the College for this work, proposed later an extension of the field of investigation and finally provided funds for the establishment of a small laboratory for the work. Cocoa, tobacco and dried fruits were the main commodities investigated when in 1932 the E.M.B. was abolished. The work was not dropped, however, for the Imperial Agricultural Bureaux offered financial assistance, though on a reduced scale, and this arrangement was maintained until the University Grants Committee made it possible for the College to provide for the basic scientific work on a permanent footing. Industry itself continued to finance *ad hoc* work but only on a short term basis.

In 1935, primarily as a result of representations by Mr. W. McA. Gracie (representing the industrial interests concerned) and Professor J. W. Munro, D.S.I.R. invited the College to carry out an extensive survey in Great Britain to determine the nature and extent of the problem of the infestation of stored produce by insects and mites. The cost of this survey was met, in part, by funds subscribed by industry. In 1939, the College submitted a report which showed that even under peace-time conditions of transport and storage, infestation was sufficiently widespread and serious to require vigorous action if effective control measures were to be established. D.S.I.R. therefore decided to set up its own research organisation which, by agreement with the College, was housed in the Biological Field Station of the College at Slough. The main function of the Laboratory during the war has been to assist the Ministry of Food, through its Infestation Branch established in 1941, in the control of those insects and mites which damage or destroy stored foodstuffs, principally bulk grain and other cereals.

The experience gained in the series of researches on infestation has emphasised the importance not only of long range, side by side with *ad hoc*, investigations, as is indeed true of all industrial research, but the necessity of keeping the long range work in the closest possible contact with commercial practice. The discovery of new laws or principles affecting the behaviour of insects in general may prove to be the simpler, if not the only approach to the problem of dealing with injurious insects.

# CHAPTER 30

# LAUNDRY SERVICE

Laundering is still largely a matter personal to the average housewife and it is not generally appreciated that laundry is now an organised industry which, in 1939, employed more than 170,000 workers. The beginnings of this 'personal' trade date from early times. Reference to it can be found in Shakespeare's plays where the launderers are referred to as 'whitsters', their old appellation. Pepys in his Diary also speaks of his wife and maids 'being gone over the water to the whitsters with their clothes' as an experiment, instead of washing at home. It is only during the last fifty years that the industry has become mechanised and research into the principles of detergent action has been conducted. Previously the washing was done by hand and the clothes cleansed by beating them in water with the aid of a stone or a piece of wood; a practice still to be seen daily in some countries, e.g., in India, where the whitster is called the *dhobie.*

### *Size of the industry*

During the 19th century laundry establishments and machines for washing were developed, and by 1901 a trade organisation was formed, the Launderers' Association, which in 1920 was re-organised as the National Federation of Launderers and changed its name, but not its set-up, to the Institution of British Launderers in 1936. The present day membership of the Institution consists of some 2,000 laundries; but if small hand and cottage laundries, employing five or six workers, are taken into account, the total number of laundry establishments in this country is between 5,000 and 6,000.

### *Early machines*

The first step in the evolution of the industry was the improvement of working appliances. The 'bucking' stool or dolly (still used in some parts of the country) was employed several centuries ago and in 1691 John Tynacke invented an engine to be worked 'by one or more men as doe worke at raising of water or washing of clothes'. Roger Rogerson in 1780 invented an entirely new machine called 'a laundry for the purpose of washing and pressing all sorts of household linen and wearing apparel.'

### *Modern processes*

The first rotary washing machine was invented in 1782 by Henry Sidgier on the principle of rotating a cylindrical cage inside an outer

shell or tub. The greatly improved rotary machines evolved later follow the same main principle. The rotary washing machine today is power-driven with a reversing gear which changes the direction of rotation of the cage after three or four revolutions. Special types have been developed especially for the washing of woollen goods with an 'interrupter gear' to ensure an automatic period of rest between the rotation periods. This minimises the 'felting' of woollen goods that have not been treated with a shrink-proof finish (see p. 181). It is the friction of wool when wet which is the prime cause of felting.

After the soiled clothes have been washed and rinsed they are hydro-extracted, dried and finished. Drying machinery varies and different types are used for different articles. The old custom of drying clothes in the open, or indoors on 'horses' when the weather was inclement, has largely ceased in urban areas; and in laundries the drying is done mainly by the continuous dryer and the drying tumbler. The former consists of an endless conveyor belt carrying the clothes suspended on clips through a steam-heated chamber and the latter dries the clothes in a perforated metal cylinder rotating in an outer casing with hot air circulating through the cage. Various forms of finishing machines are used, one of the most effective being a steam-heated press which has two or three forms. Considerable research and development work has been put into these various types of mechanisation, especially in regard to the automatic control of them, since different fabrics need different treatments and careful control is necessary for good results. For instance, woollen goods must not be worked at temperatures exceeding about 100° F. while undyed cotton goods can and should be boiled.

### *Co-operative research*

The gradual evolution of washing machinery very cursorily described above, led to the scientific investigation of washing processes and a closer examination of the principles of detergence. Particularly was it desirable for the industry, a well organised one by the beginning of the 20th century, to investigate rule-of-thumb methods and proprietary products of importance placed on the market. In 1920 the industry decided to form a co-operative research organisation and in that year the British Launderers' Research Association was formed to look into the whole scientific basis of laundry processes. No laundry in this country maintains a research staff and at present but few employ qualified chemists and engineers to investigate day-to-day troubles. The Research Association therefore has served, and still serves, to assist its members with their *ad hoc* investigations as well as to undertake more far-reaching researches.

The first step was to establish standards of colour with which

laundered work could be compared. This was followed by a detailed investigation of existing processes and methods generally used in laundries. Such matters as the use of silicates, the relative merits of hard and soft water for rinsing, laundry washing machines, the production and utilization of steam in laundries and a comprehensive investigation of bleaching methods were all subjected to scientific examination. The invention by the Research Association in 1929 of its interrupter gear was a valuable aid in the problem of washing woollen goods on a large scale; though the application of shrink-proof treatment to woollens has largely removed felting difficulties.

The fundamental principles of detergent action were also determined. The chief detergents used in commercial laundries are soap, sodium carbonate, 'modified' alkali and sodium metasilicate. The main principles of detergent action are: (1) the efficient penetration or wetting of the fabric in order to establish intimate contact between the soiling and the detergent solution; (2) the displacement of the dirt from the fibres by the detergent liquor; (3) the suspension of the removed dirt in a finely divided and stable condition, and (4) the removal of dirty liquor without re-deposition on the fabric.

*The science of laundering*

The efficiency of these processes is dependent on the relative magnitude of the forces acting on the various interfaces. The forces acting at the interfaces between air and soap solution, between air and fibre, between oil and soap solution and between soap solution and fibre have all to be taken into consideration. The first essential in a good washing process is the rapid wetting of the soiled fabric by the replacement of air in the interstices of the fabric and the establishment of intimate contact between the detergent solution and the fibres of the fabric or the soiling matter with which they are coated. The old custom was to immerse the clothes in water to which a little sodium carbonate (soda) was added to neutralise any acidic soiling matter. Research showed that far more rapid and effective results could be achieved by immersing the goods straight into a solution of soap. Less than ten years ago, such practice would have been considered extremely bad for the reason that the natural acidity of the soiled material might reduce the alkalinity of the soap liquor to such an extent that water-insoluble 'acid-soaps' would be formed, the lather would drop and no dirt removal could take place under such conditions. It was later discovered however, that these 'acid-soaps' are quite soluble in oil or greasy matter, and this fact was utilised in the development of what are now known as 'B.L.R.A. Modified Washing Processes'. In these modern processes the formation and deposition of acid-soap during the first stage of the washing process is

deliberately aimed at, and acidic substances such as sodium acid phosphate or acetic acid are added to the machine in order to achieve this condition. Subsequently a fairly strong alkali such as sodium metasilicate is added to the wash liquor; and the acid-soap dissolved in, or deposited on, the greasy soiling matter is immediately re-saponified or converted back to highly active soap. In this manner a very high local concentration of soap upon the dirt is attained and emulsification is practically spontaneous. The dirt particles are now easily detached by the mechanical action of the washing machine.

The application of these scientific principles in practice has meant that it is possible, safely and effectively, to cleanse a load of soiled goods with considerable economy of water, a 30 per cent saving in time and power consumed and some 40 per cent saving in soap over that previously found necessary.

It is interesting to note that of all the industries serving the needs of the community or a large section of it and dealt with in this Part of the book, laundering is the only one which has undertaken research entirely through its own Research Association with the aid, it is true, of grants from D.S.I.R. but without the direct action of the State as has been the case in greater or less degree with each of the other services here included.

*Advisory services*

These outlined scientific principles serve to show how the impact of science on what has been a household task in the past, brings about savings not only in time but in the life of fabrics. During World War II the Research Association played a leading part in advising the authorities on the organisation of laundry facilities both for the Forces and for ordnance factory workers. It has been estimated that savings amounting to some £1,000,000 per annum have been effected in the conservation of clothing, equipment and stores of various kinds. But this is not all. The Research Association has been able to render valuable assistance to civilian departments on such apparently diverse subjects as soap, starch, water softening, flameproofing and laundering in salt water. It has also participated in experiments carried out by the Medical Research Council for the prevention of cross-infection.

Reference has already been made to the fact that laundries do not possess research departments and, but rarely, qualified scientific and engineering staffs. The Research Association has accordingly developed a technical service by which regular visits are paid to laundries by qualified technical officers whose duty it is to check the processes employed, to advise on new methods or to suggest improvements in existing practice. Incidentally, the Association is kept informed of the tech-

nical progress being made in the industry and becomes alive to problems still requiring investigation. There is no doubt that the whole standard of laundry practice in this country has been greatly raised by the work of the Research Association.

*Educational work*

The industry has not neglected the educational side of its work and has realised that without skilled technicians the fruits of research will be largely wasted. For ten years before World War II, a scheme of technical education was in being which included evening classes in laundry technology, general science, laundry engineering, washhouse methods, etc. Some of these classes were held at the offices of the Institution of British Launderers and at various provincial centres. The technical and scientific syllabus was compiled by the Research Association and, at its laboratories, courses of instruction for young executives were organised extending over 3, 6 or 9 months. A scholarship scheme was also in force: for instance, a Leverhulme Scholarship of £120 a year tenable for 3 years at a University was awarded by a committee of the industry and of Messrs. Unilever Ltd. The Institution itself awarded two scholarships of 9 months' and four of 3 months' duration, each year; in these cases, a portion of the period of the longer scholarships and the whole of the short ones was spent at the laboratories of the Research Association. A movement is on foot to extend substantially the work and scope of the Association in the post-war period.

# PART III
## GOVERNMENT ACTION

### CHAPTER 31
## DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

When Government in 1915 appointed the Advisory Council for Scientific and Industrial Research and in the following year established a separate Department for the same purposes with its own parliamentary vote under the Lord President of the Privy Council as its responsible Minister, it took a step not only unprecedented in this country but in the world at large. The example was followed in course of time by nearly all the Dominions and in the Indian Empire as well as by the French Republic.

*Early action by Government*

So novel an experiment calls for some study of the events which led up to this remarkable fact which was indeed the final stage in a long evolution to be traced back to the 17th century and earlier. Throughout earlier times the main impulse came from the needs of national defence. In 1346 Edward III had controlled the supplies of sulphur and saltpetre, for gunpowder was first manufactured here in 1344. But long years were to elapse before in the 1820's a chemist was appointed to the staff of Woolwich Arsenal and Faraday was engaged as a lecturer at the Royal Military Academy (1829). Charles II had built the Observatory in 1675 at Greenwich for John Flamsteed the astronomer whom he had appointed 'astronomical Observator' at a salary of £100 'to correct the tables of the heavenly bodies and to rectify the places of the fixed stars for the use of his seamen'. The funds for this undertaking had been found by the sale of spoilt gunpowder but Flamsteed had to provide his own instruments for the work. Parliament, however, only recognised the need for scientific support to our growing maritime interests in the 18th century when, as explained on p. 227, it offered a prize of £20,000, won by John Harrison, for a method of determining longitude in a more accurate manner than had previously been possible.

But the equally important study of meteorology was not a govern-

ment activity till the middle of the last century, when the Meteorological Office was established as a department of the Board of Trade. The history of that Office is an example of the hesitating action of government induced by unscientific administration. In 1867 the Government, accepting the view that meteorology depends on scientific research, invited the Royal Society to appoint a committee to administer the Office. This committee was known until 1877 as the Meteorological Committee and its services were voluntary. From 1877 to 1905 it became the Meteorological Council and its members were paid. From 1905 to 1919 the Council gave way to another Meteorological Committee appointed by the Treasury with the Director of the Office as Chairman *ex officio*, the other members being the Hydrographer of the Navy and representatives of the Board of Trade, Board of Agriculture and Fisheries, the Treasury and two nominees of the Royal Society. After World War I it was suggested that the Meteorological Service should be coordinated by the strengthening of the Meteorological Committee, and that the Meteorological Office should be transferred to the Committee of the Privy Council for Scientific and Industrial Research (now D.S.I.R.). The Government decided however that the Meteorological Office should be attached to the Air Ministry. Nevertheless the suggested transfer was scientifically sound, for the future usefulness of the service depends ultimately on the extent to which fundamental research is encouraged.

*Formation of National Physical Laboratory*

At the opening of the present century the Government took the first step in the direct encouragement of organised scientific support for our industries in general. The National Physical Laboratory was established with a grant of land and an annual subvention from the Treasury at Bushy House, Teddington, a royal residence. The Laboratory was opened by the Prince of Wales (the late King George V) in 1902, and in his speech he expressed the present conviction of the nation in words that in his day were little more than a prophecy. 'I believe', he said on that occasion, 'that in the National Physical Laboratory we have almost the first instance of the State taking part in scientific research. The object of the scheme is, I understand, to bring scientific knowledge to bear practically upon our everyday industrial and commercial life, to break down the barrier between theory and practice, to effect a union between science and commerce. This afternoon's ceremony is not merely a meeting of the representatives of an ancient and world-renowned scientific Society for the purpose of taking over a new theatre of investigation and research. Is it not more than this? Does it not show in a very practical way that the nation is beginning to recognise that if her commercial

supremacy is to be maintained greater facilities must be given for furthering the application of science to commerce and manufacture?' Thoughtful people had realised the significance of the foundation of the *Physikalisch-technische Reichsanstalt* by the German government and the late Lord Rayleigh, then President of the Royal Society, interested his brother-in-law, A. J. Balfour, in the need for establishing a national institution for the determination of the many standards and constants needed by modern industry. Later, a series of technical high schools were established in Germany, the most famous of which was the great *technische Hochschule* at Charlottenburg, which in time reached the full status of a university.

*Other developments previous to World War I*

The rapid growth of Germany's industrial power, and the political controversy here over protection and free trade, had brought home to the public the fact that five-sixths of the nation's food was imported from overseas and that the major part could be paid for only by the export of manufactures. Thenceforward the establishment of the Engineering Standards Committee by the Institution of Civil Engineers, later to become, with much wider activities, the British Standards Institution under Royal Charter, the transfer of the Imperial Institute to the Government in 1902, and the establishment of the Imperial College of Science and Technology (a British Charlottenburg) by the fusion of the Royal College of Science, the Royal School of Mines and the Central Technical College of the City and Guilds of London Institute, were evidence of the growing interest of the public and Government in the progress of industry and its scientific bases. The charter of the College defined its purposes as 'to give the highest specialised instruction and to provide the fullest equipment for the most advanced training and research in various branches of science, especially in its application to industry and to do all or any of such other things as the Governing Body hereinafter instituted consider conducive or incidental thereto having regard to the provision for those purposes which already exist elsewhere'. But the assistance of Government remained indirect.

The needs of defence in a new direction, however, soon led once more to direct Government intervention and later to the foundation of a new civilian industry, that of aircraft construction. In 1909, on the initiative of Mr. (later Lord) Haldane, then Secretary of State for War, an Advisory Committee for Aeronautics was appointed by the Government, to advise the Prime Minister on the encouragement and organisation of research in this field (see p. 296). There was indeed no man of his time who had so great an influence as Haldane on the development of university and higher technological education and research. He was

chairman of three University Commissions, and the establishment of the Imperial College and of the Aeronautical Research Committee were alike due to his influence. But this was not all; without his strong interest the Department of Scientific and Industrial Research would never have become a department of State. This interest was shared and continued by Lord Balfour after World War I and put the new organisation on a permanent and enlarged basis. At last both the great political parties were committed to the support and encouragement of industrial research.

### *Action as a result of World War I*

When World War I broke out in August 1914, it was proved how dependent the country was on enemy industries for products essential in its defence. We were making less than a couple of dozen kinds of optical glass compared with over a hundred made by Germany. We could hardly make a tithe of the various dye-stuffs needed by our textile industries. In particular we had no supply of the khaki dye necessary for our military uniforms, and a mixture of existing dye-stuffs giving an approximate colour was hurriedly supplied by Messrs. Levinsteins. The only reliable magnetos were made by the German firm of Bosch. Many important drugs and pharmaceutical products were German; even the tungsten for steel manufacture and zinc came from Germany though produced from ores of Empire origin. Most needed of all perhaps was the chemical glassware needed by our steel manufacturers for the routine testing of their products, and the Board of Education had to make a hurried census of the supplies in the technical colleges of the country in case it might be necessary to commandeer them. A committee was appointed by the Board of Trade with Lord Haldane as chairman 'to consider and advise as to the best means of obtaining for the use of British industries sufficient supplies of chemical products, colours and dyestuffs of kinds hitherto largely imported from countries with which we are at present at war', and on the advice of a sub-committee under Lord Moulton's chairmanship a company was floated for the manufacture of dye-stuffs with a share capital of £3,000,000 and a Treasury advance of £1,500,000 secured by debentures. A further grant of £100,000 was also promised for research over a period of ten years. This company, 'British Dyes', absorbed several existing companies and now forms an important part of Imperial Chemical Industries Ltd. These gaps in our industrial equipment led to the submission of a memorandum to the President of the Board of Education prepared at Christmas 1914 by the universities branch of that Board, pointing out the failure of our universities to train sufficient numbers of research workers and making proposals for remedying the consequent weakness of our industries in



Plate XV. Viscount Haldane, O.M., F.R.S.
One hour study in oil colour by Fiddes Watt, R.S.A.

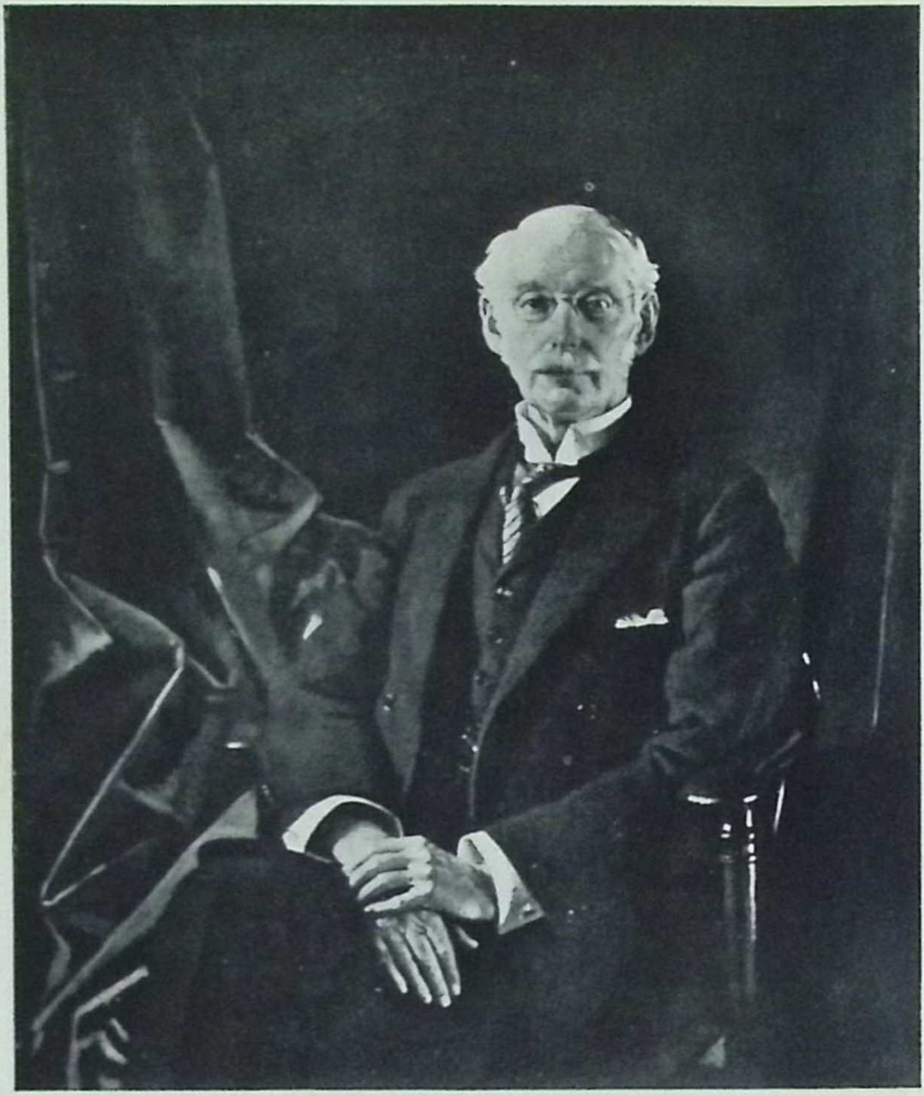


Plate XVI. Sir Charles Parsons, O.M., F.R.S.
Painting by Sir William Orpen, R.A.

this regard. The memorandum was referred to a small secret committee under Sir William McCormick, the Chairman of the Advisory Committee on Grants to Universities, at that time attached to the Board. The committee worked to such good purpose that when in May 1915 a deputation from the Royal and other learned Societies interested in chemistry was received by the Presidents of the Board of Trade and Board of Education asking for 'Government assistance for scientific research for industrial purposes, the establishment of closer relations between the manufacturers and scientific workers, and teachers, and the establishment of a National Chemical Advisory Committee for these purposes', the Presidents announced that the Government had decided on a much wider attack on the problem. They intended to encourage research not only in chemistry but in all other sciences affecting industry. Thus for the first time the State had resolved to take a hand itself in promoting industrial research.

*D.S.I.R.*

This is how the Government decided to proceed. On the 23rd July, 1915, a White Paper was issued entitled 'Scheme for the Organisation and Development of Scientific and Industrial Research' (see Appendix I) designed to establish a permanent organisation for the purpose. 'It is in no way intended' said the White Paper, 'that it should replace or interfere with the arrangements which have been or may be made by the War Office or Admiralty or Ministry of Munitions to obtain scientific advice and investigation in connection with the provision of munitions of war.' The scheme was to 'operate over the Kingdom as a whole with as little regard as possible to the Tweed and the Irish Channel. The research done should be for the Kingdom as a whole, and there should be complete liberty to utilise the most effective institutions and investigators available, irrespective of their location in England, Wales, Scotland, or Ireland. There must therefore be a single fund for the assistance of research, under a single responsible body. The scheme accordingly provides for the establishment of—

(*a*) a Committee of the Privy Council responsible for the expenditure of any new moneys provided by Parliament for scientific and industrial research;

(*b*) a small Advisory Council responsible to the Committee of Council and composed mainly of eminent scientific men and men actually engaged in industries dependent upon scientific research.

The primary functions of the Advisory Council will be to advise the Committee of Council on

(i) proposals for instituting specific researches;

(ii) proposals for establishing or developing special institutions or

departments of existing institutions for the scientific study of problems affecting particular industries and trades;

(iii) the establishment and award of Research Studentships and Fellowships.'

The Advisory Council was to be available, for consultation and advice, to the several Education Departments as to increasing the supply of research workers, to keep in close touch with all Government departments concerned with scientific research and to act in intimate co-operation with the Royal Society and other scientific associations, societies and institutes as well as with the universities, technical institutions and other organisations in which research is or can be efficiently conducted. These bodies could make proposals for consideration by the Advisory Council, which could receive proposals from individuals and themselves initiate them. They were also to use all possible means to interest and to secure the co-operation of persons directly engaged in trade and industry.

Accordingly an Order in Council dated 28th July, 1915, established a Committee under the Lord President, 'to direct, subject to such conditions as the Treasury may from time to time prescribe, the application of any sums of money provided by Parliament for the organisation and development of scientific and industrial research'. Parliament placed a sum of £25,000 at the disposal of the Committee and offices were provided in the Board of Education. The Advisory Council as then constituted consisted of seven members, all fellows of the Royal Society, and a majority closely concerned in scientific industry with Sir William McCormick, the Chairman of the University Grants Committee, as Administrative Chairman (see Appendix I).

There were several features in this plan without precedent in British practice. In the first place all proposals for the encouragement or development of research made to the Committee stood referred to the Council for their consideration. Next, the Council could initiate proposals of their own. Thirdly, advice to the Departments of Education and other Government departments, if asked for, lay with the Council. In other words, the technical advice to the responsible Minister was placed permanently in commission and entrusted to a permanent body of independent and distinguished men of science and industrialists, and not to officials either of the Committee itself or of other Departments of State.

It was no new thing that the first steps in the establishment of a new Department of State should be the appointment of a Committee of the Privy Council. This had been the history of the Board of Trade and of the Board of Education constituted as such by the Education Acts of 1902 and 1903, by the amalgamation of the duties of the Committees of

Council for Science and Art and for the old Education Department. Both the Board of Trade and the Board of Education were established by Acts of Parliament defining their powers and duties, but when the Government established in 1916 a new Department of Scientific and Industrial Research with its own vote in the Estimates and its own office and establishment, this development was not defined by legislative enactment nor has it subsequently been so defined. And for a very good reason. It was clear that if the Government was to obtain the co-operation of the industries in the prosecution of research the Department must be free from any suspicion of being concerned either in their regulation or in their commercial dealings. The Minister responsible had accordingly to be unconnected with any administrative Department of State and this led naturally to the selection of the Lord President as the appropriate Minister, for he is free from administrative responsibilities and has relations with the whole United Kingdom. He is not for these reasons, however, free from parliamentary control, for the policy of the Department can be reviewed and criticized on the submission of the annual Estimates and is subject to questions by any member of the House. The functions of the Advisory Council, which is the chief source of departmental initiative, are laid down by the Order in Council in only general terms and thus a wide discretion is left to the Department in carrying out its responsibilities, a very necessary factor in dealing with the constantly changing conditions of industrial progress under the impact of scientific advance, a freedom very difficult to secure under the necessarily rigid definitions of an Act of Parliament.

*Initial policy of Advisory Council*

With these general considerations in mind it is now possible to explain in outline how the Department has dealt with its three outstanding policies as laid down in the Order of Council for the guidance of the Advisory Council.

*Encouragement of research workers*

At an early stage the Advisory Council confirmed the fears of a shortage in the number of research workers. The Consultative Committee of the Board of Education reported in 1916 on the need for enlarging the output of our universities and the Prime Minister's Committee on the Teaching of Science under the chairmanship of the President of the Royal Society urged 'that a large increase in the number of students passing through our universities is a matter of great national importance'. The plans recommended by the Advisory Council for the extensions of industrial research as outlined below were designed to satisfy an increased demand for trained workers already inadequate for existing

needs. The Department could not ensure a larger entry to the universities and technical colleges or encourage young undergraduates back from the war to complete their studies, but it could help those who had acquired enough knowledge and had shown a capacity for original work in science to begin research. While implementing this policy the Advisory Council had the following aims. They wished to stimulate the growth of schools of research in the universities under the leadership of creative minds, for only thus could a steady supply of well-trained, young researchers be secured. This was strongly urged by the late Sir George Beilby. To this end they sought the active co-operation of the professors of science, and accordingly they made the grant to a student in training for research depend largely upon the recommendation of his or her professor and not merely upon the results of an examination. The grants were not to be scholarships and honorific awards but maintenance allowances to enable the students to pay their fees and keep themselves during their periods of training. Consequently although upward limits for the allowances were indicated, it was left to the university authority to make recommendations of the amount required in each case from their knowledge of the individual circumstances. The period of the allowances was fixed at two years. In the case of metallurgy the period was extended (later) to three years in order to enable students who had graduated in another faculty to take up the subject, for there was a grave shortage of metallurgists. The intention of the awards was to discourage at this stage in a young student's career any attempt to attack the problems of applied research, for without a firm grounding in the fundamentals of pure research no real advance in the application of its results to the needs of industry could later be hoped for. Incidentally the Council watched carefully the recommendations of the professors with a view to a first assessment of their value, and thus to avoid any tendency to accept as swans young people who in fact were of some smaller breed.

During the financial year 1916–17 allowances to students for training in research amounted to approximately £1,000 despite the withdrawal of young men for military service. Two years later the annual expenditure was doubled and in 1921–22 had risen to £23,720. In 1922-23 the number of students in training rose to 252; for the next three years they averaged 216 and thereafter the number varied between 165 and 116 in any one year.

At the time of the institution of this scheme for training students in research it was recognised that it was a temporary provision, for the Department was in effect assuming functions separated from its main purposes and entering upon the educational field. Moreover, other assistance of the kind was coming into existence and it was expected that

ultimately funds from other sources would replace the departmental provision. Some evidence that this occurred is shown by the fall in the number of awards made as the scheme progressed.

In 1917 the Council also gave direct help to young research workers of ability. Grants were made to graduates of promise to help them to continue their researches for a time free from the need to find other employment. These grants in 1928–29 were replaced by the institution of a new form of award of the nature of research fellowships; they are called Senior Research Awards and of value of £300 a year, tenable for three years. These awards are definitely honorific in nature and a standard of attainment is expected similar to that expected from a fellow of his college. The number of these awards in being in any year varies from 10–18.

The maintenance allowances to young graduates and the Senior Research Awards are designed to assist young and promising individuals. The Council also took means to encourage the prosecution of researches of special timeliness and promise at the universities which otherwise would not be undertaken or would not be pursued with the rapidity desirable. For this purpose grants were made to professors and senior lecturers to enable them to engage suitable assistants and acquire essential apparatus to carry out researches which appeared to the Council of importance. The number of these grants made yearly varies and most of them continue for at least two years. In the five years including 1939 they have ranged in number from 50 to 59 each year.

Finally the Council gave grants extending over a number of years to distinguished men of science to conduct and establish important researches with which they were associated, in fields where they were acknowledged leaders. As an example of such grants may be mentioned those given to Sir William Bragg for the foundation and development of his X-ray work, later financed by the Royal Institution. The early stages of the magnetic laboratory at the Cavendish Laboratory under Lord Rutherford is another example.

### *Founding of Research Associations*

One of the most important lines of policy adopted by the Advisory Council was the institution of a scheme of co-operative Research Associations. Their establishment and history are described in the next chapter. Two anecdotes from this period will explain better than a long description the difference between the attitude of some industrialists then and now.

The first was a remark made by the chairman of the board of one of the biggest companies in an industry based not on a mediaeval craft but on the application of modern science. In reply to arguments urging

the importance of research in the interests of the industry as a whole as well as for individual firms and the need for long views, the directors' chairman replied, 'To be frank I am only interested in researches that produce results in a year's time.' Today his company is not only a big contributor to its Research Association but it also has one of the largest and best-equipped research laboratories in the trade.

It was after a visit to the North when Sir William McCormick and the Secretary of the Department were returning from a long and largely attended conference in the Mayor's parlour that Sir William remarked 'We are sent to preach the gospel with a bible in one hand and nothing in the other'. Therein was the germ of the idea of a fund with the help of which contracts could be made with industries over a period of years, and from it sprang the scheme for the Million Fund to be held by the Imperial Trust for Scientific and Industrial Research and to be used over a period of years in grants to approved Research Associations.

*Co-ordinating activities*

Early in its history the Department realised that one of the weaknesses of scientific research in the country before the war was the absence of co-ordination between the various centres of research both in the universities and in the laboratories of Government departments. It had been emphasised in the original memorandum that formed the first step towards the establishment of the Department of Scientific and Industrial Research. In 1917 assessors to the Advisory Council were appointed from each of the Departments of Government interested in scientific research. They received regularly the agenda of the Council and could attend its meetings whenever matters of interest to their Departments were under discussion. As the result of a Cabinet decision in 1919 a series of co-ordinating Research Boards for the Fighting Services was appointed, with a view to avoid overlapping and to ensure the utmost economy of expense and personnel in the technical work of the three Services. They included representatives of the scientific staffs of the Defence Services and of civilian departments materially interested, together with independent men of science.

In the same year the Department decided to establish a Records Bureau to assist the exchange of information and to promote the co-ordination of the work done by the newly formed Research Associations, and the Bureau was also made available for the Co-ordinating Research Boards. In 1928 however, the Government decided to dissolve the Co-ordinating Boards in Chemistry, Engineering and Physics, but the Radio Research Board whose work was largely pioneering and which had a station of its own at Slough was continued (see p. 284).

# CHAPTER 32
# RESEARCH ASSOCIATIONS

One of the most far-reaching movements started by the Advisory Council was the scheme of co-operative Research Associations and since it was not only unique in character but represents a major factor in the history of British industrial research, a full account of its origin and progress is called for.

*General purpose of the scheme*

The scheme was the result of much thought by the Advisory Council after consultation with leading industrialists and its scope and purpose were set out in a pamphlet entitled 'The Government Scheme for Industrial Research' which opened with the following words. 'Much will depend upon the way in which this money (i.e. the Million Fund) is spent. The independence and initiative of the British manufacturer have contributed largely in the past to his success. After the war he will need all possible assistance in undertaking and developing research work as a means of enlarging his output and improving its quality. But if the help is to be effective, it must increase his independence and initiative. It must avoid chaining him to the routine of Government administration, however efficient. It must be so given as to enlist his active support. To the initiative of the manufacturer the improvement of old and the discovery of new industrial processes in this and other countries have largely been due. It has been the co-operation of progressive industry with science which has led to the practical application of the results obtained in the laboratories of scientific men.'

This preamble clearly stated that British industry in the past had done much and, as has been indicated in earlier chapters of this book, had led the world in many directions; but industry *as a whole* needed further equipment if it was to face successfully the competition of the future. That could only be achieved, in the view of the Advisory Council, by giving a lead towards further endeavour on a co-operative basis.

The first essential, therefore, was to make industry realise that these co-operative research associations were to be autonomous bodies, created by the initiative of the leaders of the industries concerned. They were to be organised and controlled by governing bodies elected by the subscribing firms. The programmes of research were to be framed by industrialists and carried out by staffs appointed by them. The results obtained whether protected by patents or otherwise were to be the

property of the members. The Government was normally to claim no share in the profits nor was it to control or even to approve the programmes of research. The associations were constituted as Companies limited by guarantee and working without profit, that is, without division of profits among their members in the form of dividends.

The Advisory Council felt that if the responsibility was thus placed upon the industrialists both for organisation and the control of the programmes, the results when achieved, and to which the members would be party throughout, would be put into practice. Results obtained in a Government laboratory if published might well be used more effectively by foreign competitors who, as a rule, are much more acquisitive in such matters than British firms. Moreover the Advisory Council held strong views from the inception of the scheme, and throughout its progress, that the grants given must be administered in such a way as to dispel, so far as possible, the inherent dislike and distrust on the part of industrialists of Government interference. They knew well the individualistic outlook of British manufacturers and felt it essential to secure their confidence.

The power of a Government department is not increased merely by adding to its duties, but by the wise devolution of detailed control on to the shoulders of those best fitted to exert it. Especially is this true of a department closely associated with industry. A government department cannot hope to know with any intimacy the conditions that obtain in the variety of industries served by the Associations which cover two-thirds of the total manufactured exports of the country. It cannot exercise influence in industrial research activities except through the agency of the captains of industry. There are many things connected with industrial endeavour which can be learned and appreciated only by working for years in the atmosphere of the industry concerned. The wisdom displayed by the Advisory Council in laying down the principles enunciated has been amply proved. The considerable success achieved by the scheme is mainly due to the unselfish way in which the farsighted leaders of industry have devoted themselves to its furtherance, and they would not have done so unless they had been given freedom.

One of the main objects of the co-operative scheme was to enable the organisations to undertake work which could not be dealt with satisfactorily by individual firms. Prominently in this category of investigations were the long range problems on the solution, or even partial solution, of which the future prosperity of the industry as a whole may well depend. Such researches take long and patient exploration and need to be studied in laboratories where the insistence of shorter range problems is not so great as it is likely to be in a works laboratory. Moreover it is these endeavours which have special interest for the Government,

since upon their pursuance the future national well-being of the country may rest.

These long-range problems appeal only to the more far-sighted manufacturers. The general body wish to see at an early date what they are getting for their money. The 1918 document accordingly set out the following immediate privileges which would accrue to a subscribing firm.

(*a*) It will have the right to put technical questions and to have these answered as fully as possible within the scope of the research association.

(*b*) It will have the right to recommend specific subjects for research, and if the governing body of the association considers the recommendation of sufficient general interest and importance, the research will be carried out without further cost to the firm making the recommendation and the results will be available to all the firms in the organisation.

(*c*) It will have the right to the use of any patents or secret processes resulting from all researches undertaken, either without payment for licences, or at any rate only on a nominal payment as compared with firms outside the organisation.

(*d*) It will have the right to ask for a specific piece of research to be undertaken for its sole benefit at cost price and, if the governing body approve, the research will be undertaken.

In connexion with the first of these privileges, the scheme contemplated the formation of bureaux of information attached to the associations to disseminate among members up-to-date information relating to their technical operations, available from all sources at home and abroad. Translation services would be numbered among the activities of these bureaux.

In short, these Research Associations to be established in all the important manufacturing industries of the country were to act as central agencies to stand behind and supply with new ideas, new methods, new standards of quality, the principal industries of a nation dependent for its existence on its power to feed itself by means of the sale abroad of its manufactured products.

### *Advantages to small and large firms*

It must not, however, be thought that the Advisory Council were oblivious of the fact that many of the leading firms already had extensive research laboratories of their own or that the position won by British manufacturers in the past had not in many cases been secured by the application of science to their products. But there were hosts of small firms up and down the country which had nothing of the kind to assist them but which by subscribing to a co-operative organisation could in future be equipped to a degree and in a fashion they could not hope for

as individual entities. It has been estimated that about one-third of British industry is conducted by firms with 100 employees or less. (The actual figure is given as 32·2 per cent in Professor R. S. Hutton's paper on 'Higher Technical Education', City and Guilds of London Institute, Nov. 1943.)

But it may be asked what inducement there was for the large and scientifically well-equipped firms to identify themselves with the Associations. In the first place they would be in a better position, by means of their scientific staffs, to interpret the results achieved and adapt them for their own purposes. Especially would they be able to make use of the long-range investigations. There was another reason for the large firms to join the Associations. The strength of a chain depends on that of its weakest link; and it was to the advantage of the large firms to increase the reputation of the whole industry with which they were connected in the eyes of the foreign buyer of its goods. It is important to record that some of the strongest supporters of the Research Association movement are the large and powerful firms and corporations. They have probably given more than they have received and it is mainly the arguments cited above and their desire to identify themselves with the national movement which have made them its supporters.

It should not be thought that industrial firms regard their research departments as organisations created solely for their own purposes. In the course of their investigations results of wide scientific interest emerge and these are made available by publication in scientific journals and the proceedings of learned societies. As an illustration, the members of the scientific staff of one of the leading firms in the electrical industry have published no less than 312 reports with the consent of the firm during a period of twenty-four years. These communications were contributed by 107 individuals either as sole or joint authors, seven of them women. In addition a considerable number of important lectures was given by the Director of the laboratory and senior members of the research staff.

### *Scale of initial grants*

The grants from the Million Fund were given at the outset on a £ for £ basis on all income raised, provided a certain minimum industrial income was guaranteed. There was also an upward limit placed upon the grant aid in each case. The grants were guaranteed by the Department for a period of five years and the possession of a sufficient capital sum (the Million Fund) enabled the Department to give these unequivocal promises.

It was thought that after a period of five years the usefulness of the Associations would be sufficiently established to warrant the hope that

thereafter the industries would maintain the Associations without further financial assistance from the State. This anticipation proved too sanguine as will be explained shortly. Some of the chief factors which operated against the rapid growth of the movement will also be enumerated.

*Conditions of grant*

The main condition attached to the grants was that there must be 'due prosecution of research' and the Department was to be the final arbiter on that question. There were other conditions attached in the national interest: Every report had to be submitted to the Department, which could veto its publication or even dissemination among members. With one exception this power has never been exercised except under war conditions. Similarly, a 'complete' specification for a patent cannot be taken out without the previous consent of the Department, for the filing of such a specification constitutes publication.

The Department has the right, under the conditions of grant, to communicate a report in confidence to any section of the Department or to another Home Government department after informing the Association of its intention to do so; but that department is not at liberty to pass on the information to any firm with whom it may be in commercial relationship. The Department also has the right, after consultation with an Association, to communicate the results of its investigations to other industries on such terms of payment and other conditions as may seem reasonable to all the parties concerned. The Department has the further right to inform another Research Association of the title of a report which is likely to be of interest to that Research Association. It is then a matter of negotiation between the two Associations to decide how far and on what terms the contents of the report shall be made available.

Finally, the Department has the right, which it may or may not exercise, to appoint one or two scientific or industrial representatives on the governing body and in addition one of its own officers to attend meetings but not to vote.

These conditions are not onerous, and have been cordially welcomed by Associations as measures of help and not restriction.

The grant aid from the Department is given for the furtherance of the general research purposes of the Association and no control is exercised over the precise way in which the grant is expended. Payment for services rendered to the Department or to any other Government department is in a different category. It does not rank as income for grant-earning purposes, and is made for a specific piece of work for which the Association has been chosen. During World War II considerable sums have been paid to some of the Associations for carrying out important

national work, some of it of a highly confidential nature, and the work has been carried out to the specification of the ordering departments. Payment for work for the exclusive benefit of a member firm is also not grant-earning.

Financially the Government offered more than the grants from the Million Fund. Negotiations took place with the Board of Inland Revenue who agreed that subscriptions paid to Associations, operating under the conditions indicated above and approved by the Department, would automatically be recognised as business costs of the firms and would not be subject to income or excess profits taxes. The general income of the Associations would similarly be free of income tax. This was a material concession which has subsequently been re-examined and supported by a Royal Commission on Income Tax. During World War II, with income tax at 10s. in the £ and 100 per cent Excess Profit Tax, the ruling has been doubly useful. A further concession was granted by the Chancellor of the Exchequer in his Budget speech of 1944. Contributions for the capital purposes of Research Associations will be similarly exempt.

*Progress of the Scheme*

The progress of the movement falls into three main phases. The first phase was the initial five years during which the Million Fund was expected to be spent and the Associations sufficiently established to stand financially on their own feet. During 1918 four Associations were licensed by the Board of Trade; ten in 1919; nine in 1920; and one each in 1921 and 1923. In the aggregate they covered a very wide range of British industry (*see* Appendix II). During this phase the aid from the Government was on the basis of £ for £ on all income raised with the proviso of an irreducible minimum industrial subscription and an upward limit to the amount of the grant.

The second phase began at the close of the first quinquennium. Although the Million Fund had not been exhausted, there was the understanding that on its exhaustion the Associations were to become self-supporting. That was the footing on which Parliament had voted the money in 1917 and naturally the Treasury took cognisance of the fact. Steps had to be taken to give effect to the original conception, though the Advisory Council had considerable doubts whether it would not result in the demise of several of the organisations. They were as yet tender growths; many, in fact most, had done little more than establish themselves tentatively in the eyes of their respective industries. It takes the best part of five years for research organisations to find (or build) suitable premises, to collect a suitable staff and to plan the necessary organisation. Moreover, industry by the close of the

period had begun to experience the grave depression that followed World War I, and firms were seeking ways in which their expenditure could be decreased, not enlarged. It was of little avail to say, true though it was, that the worse the position of an industry in the world's markets, the greater the need for research and the improvement of the quality of its goods.

It was in this atmosphere of depression that the Department instituted its scheme of diminishing block grants whereby at the end of a second quinquennial period each Association should become self-supporting by stepping up the industrial income each year by 20 per cent jumps, the Department's grants receiving the same percentage reduction.

Before the close of the second phase the Advisory Council realised that their earlier doubts were being fulfilled and that insistence on making the Associations immediately self-supporting would result in the collapse of a scheme their belief in which had never wavered. Accordingly the necessary representations were made and a modified scheme devised in place of the diminishing block grant arrangement. The new plan was called the 'datum-line' scheme and can be described thus:—Each Association was examined to see what minimum scale of expenditure might in all the circumstances be regarded as a more or less satisfactory nucleus for a co-operative research organisation in the field concerned. That figure was termed the 'datum-line figure' and up to that amount no grant was paid in respect of the trade income. But above that figure and up to a maximum represented by the datum figure itself, the Department agreed for the time being to contribute £ for £. If, therefore, full advantage of the offer were taken, the Government would contribute one third of the total income or 10s. against £1 of income from industrial sources.

During this phase the Advisory Council, instigated in large measure by one of its leading industrialist members, recommended the appointment of a committee, presided over by the then Chairman of the Advisory Council, Lord Rutherford, to examine the position of Research Associations and to report through themselves to the Government on the subject. The committee included such eminent industrialists as Sir Josiah Stamp (later Lord Stamp), Sir Hugo Hirst (later Lord Hirst), Sir Alan Anderson, Sir Arthur Balfour (later Lord Riverdale), Sir Kenneth Lee, and Sir John Cadman (later Lord Cadman). This committee, after examining the Research Association movement as a whole and its progress, recommended strongly that Government support should be continued and a real effort made to place the Associations on a more satisfactory financial basis. As a result the scheme of grant aid in operation today came into being. It consists of a modification of the datum-line

scheme on the following lines:—The case of each Association is considered on its merits and no general formula, as was applied in the datum-line scheme, is used. Having regard to the stage of development reached, the financial circumstances of the industry concerned and other factors, a block grant guaranteed for five years in the first instance is offered provided a minimum industrial income is forthcoming. The ratio of the block grant to the industrial income required to earn it is decided by the Advisory Council and varies according to the needs of the case. Over and above the block grant, additional grant, again in a ratio suitable to the needs of the particular case, encourages expansion.

The announcement of the Government's decision arising from the representations of this Committee and the Advisory Council was made by the President of the Board of Trade (Mr. W. Runciman) at a banquet given by Sir Kenneth Lee at which no less than 1,000,000,000 sterling of industrial capital was represented (Plate III). Next day the details of the scheme were placed before a conference of representatives of the Research Associations, presided over by Lord Rutherford, and the leaders of industry were invited to look into the matter and come to the Department with proposals for putting their respective Associations on an enlarged and more satisfactory footing.

Since that date much progress has been made and in recent years large developments have occurred, but even today the movement is still far from being what it might be as an instrument for the benefit of industry. The graph shown in Appendix III indicates the growth in the financial resources of the Associations during the last 10 years. A committee appointed by the Federation of British Industries has published a report on the subject of industrial research ('Industry and Research', Oct. 1943), in which emphasis is laid on the meagre resources still at the command of most of the Associations.

Such then are the early phases through which the Research Association movement has passed and, in the sections devoted to the brief examination of the main industries of the country, some reference is made to a few of the achievements of individual Associations (*see* Part I).

### *Early errors*.

The Department of Scientific and Industrial Research not unnaturally made mistakes in its sponsoring of the movement. One of the biggest mistakes, easily recognised now, was the making of grants to co-operative organisations on a basis since proved to be inadequate. But if the views of today had been pressed at the outset, few Associations would have come into existence and no broad outlay for industry as a whole would have been achieved. If at that date the Advisory Council had said, as they are inclined to say today, 'Are you prepared

to find at least £20,000 a year to make a start?' the industrialists would probably have said, indeed it is certain, 'We have not the least chance of persuading our industry by voluntary means to provide anything like such an annual sum for what is a novel and untried experiment.' In the result however the scheme at a very early date became operative in the major proportion of British manufacturing industry.

The second mistake was the attempt to implement the understanding on which the Million Fund was voted and to bring about, or try to bring about, the early financial independence of the Associations. Here the Advisory Council were in a difficulty. They were convinced of the necessity of making industry responsible for the inauguration and the conduct of the organisations. That, in their view, was a primary essential and further, the organisations were intended to become self-supporting. When, therefore, the Million Fund began to show signs of exhaustion, the Council found it difficult to do other than try to fulfil the original intention. Hence their decision to institute the diminishing block grant system. Fortunately before that system had progressed too far, the Council realised what the result would be and addressed themselves to bringing about a different policy.

The Advisory Council have recently further revised their views and have come to the conclusion that it is in the national interest for the State to continue indefinitely its financial support of these organisations—the latest stage in development. The well-being of this country is mainly dependent upon its industrial prosperity. Looking ahead it is of the first importance that British industry should be equipped to make advances ahead of its rivals in the international struggle for an adequate share of world trade. To achieve this it must be forward in breaking new ground, and in adopting and developing new processes by which the quality and price of its goods will secure customers. In the national interest it is all-important that long-range research should be carried on. This type of research does not make much appeal to the average manufacturer, obsessed as he is, and will be, by the task of dealing with his day-to-day problems. Here are ample grounds on which continuous State aid to the Research Associations can be justified.

What has been said may have created the impression that Research Associations can solve all the scientific problems of industry. But the Associations should be additions to, not substitutes for, individual efforts. Every firm of importance in this country ought to have a scientific staff to deal not only with the day-to-day troubles of the firm but to undertake, or at least to appreciate the significance of, deeper-seated investigations. One of the greatest services that a Research Association can render is to convince its member firms that they should establish their own scientific organisations.

*Research Associations during World War II*

The chief phases through which the Research Association movement passed between its establishment and the outbreak of World War II have been described. But the events which then occurred merit examination. The conditions that obtained in 1939 were very different from those in 1914. In the first place there existed the recently formed Research Associations. After World War I the opinion was often expressed that if Research Associations had been in existence, the task of the Government in securing the scientific and technical collaboration of industry would have been greatly simplified. The scientific problems of World War I were, as suggested elsewhere, mainly chemical problems. Those of World War II were physical and mechanical in the main; and problems involving team-work rather than individual effort.

Steps were taken in 1939–40 to review the scientific organisations connected with industries, including the Research Associations, and to register teams of workers employed so that their essential elements should not be broken up without previous reference to the Department. In World War I there had been many instances in which a man was taken to shoulder a rifle when he would have been employed much more profitably in scientific work connected with the war. Arrangements to this end were made by the Central Register of the Ministry of Labour by which proper use was made of scientifically-trained men. The system may well serve as a basis on which recruitment to industry after World War II may be encouraged and assisted. The Department thus ensured that the staffs of Research Associations were reviewed, and subsequently, first under the system of 'Protected Establishments' and then under the Essential Work Order, the staffs of Research Associations were duly considered, according to the degree to which their members were engaged on work of national importance.

Despite these steps the Research Associations laboured under a sense of frustration. They were more than anxious to do their utmost in the national crisis and to bring into the common stock the accumulated scientific knowledge they possessed. Knowing as they did the industrial difficulties inherent in the problems of supply, they were peculiarly able to help in those matters. But inadequate use was made of them in the early years of the war. Government Departments were willing enough to acquire from Research Associations members of their staffs as members of their own scientific establishments but were slow to entrust problems to Research Associations for solution. As the war progressed, however, the position gradually improved and the Associations were given work to do which satisfied their natural desires and furnished important contributions to the national effort.

There are several instances where a Research Association has derived

great additional support from industry by reason of war contracts. Firms found themselves unable to carry out the contracts entrusted to them by Government without the assistance of the Research Associations and consequently the membership of the Associations increased considerably. How far these firms will continue to maintain their membership after the war when its stimulus has passed remains to be seen and depends on the enlightenment they have meantime gained. The war has had one effect that may prove of lasting advantage. The shortage of certain materials and the need for improvisation in many directions have brought the Associations face to face with new industrial problems and have enforced the use of substitute materials. The experience thus gained may well prove of value in the post-war period and enable member firms to make use of knowledge obtained in fulfilling Government orders.

To conclude this chapter a sketch follows of what should be, in our opinion, the functions and scope of a well-found and properly financed Research Association; together with a discussion of the methods of securing industrial support for its finance.

*Functions of Research Associations*

(i) One of the main functions of an Association should be to prosecute continuously those long-range researches on which the future of the industry will largely depend. This is the objective in which the Government are mainly interested and it should be conducted with a due sense of its importance and obligation to the nation.

(ii) Under the guidance of its council, and its programme committee, an Association should include objectives which are likely to furnish early answers to problems immediately confronting the industry. Some of these will be found to involve more deep-seated problems than at first appear and may have to be included wholly or in part among the long-range problems. The mere formulation of such problems by industrialists conversant with them will throw up issues which would not be apprehended by those less familiar with their implications.

(iii) The most important factor of all in the well-being of an Association is the staff, in particular the director. If the director is the right man, the staff appointed by the council of the Association at the instance of the director will probably also be right. It does not in the least follow that the man to direct the Association for one industry is the right man for another. Much depends on the nature of the industry and its background. One quality is essential in every case. The director must be of the type to secure rapidly and whole-heartedly the confidence of his industry. Naturally he must be a person with scientific knowledge but he must also possess tact and statesmanship. He must be a person who

has the confidence of his staff and gives them that degree of freedom of action which inspires them to show their worth. He must be a leader but not a dictator, and bring to the scientific problems that refreshing audacity of thought and uncommon sense which are characteristic of a vivid scientific imagination. There are few posts more difficult to fill satisfactorily than that of the director of a Research Association; and yet on him will largely depend its success.

It is a mistake to suppose that the industrial experience of a director must necessarily have been gained in the industry, for which he is going to direct research. Especially is such an idea dangerous in the case of an old industry based upon the development of what was originally a craft. The desirable audacity of thought is likely to be lacking. It is also a mistake for the council of an Association to interfere too much in the programme of the long-range work which the director will be responsible for carrying out. When the General Electric Company of America invited Dr. Whitney of the Massachusetts Institute of Technology to become the first director of their research laboratories and when he was joined by Dr. Coolidge and Dr. Langmuir, the Company made it plain that the scientific men would have a completely free hand in determining the programme of research to be undertaken. A similar freedom has been granted to the director of research in the General Electric Company of Great Britain and to the scientific heads of other important companies. The wisdom of this has been amply justified by the profits made by the companies in the production of new industrial devices. It is indeed as true for large scale scientific research as in industry itself that the maxim of Andrew Carnegie is sound. When he was building up his great steel works he was accustomed to say, 'Find the man and let him alone.'

(iv) The staff under the director should include men of scientific distinction in close touch with scientific societies and regarded by their colleagues in universities and elsewhere as experts in their own particular field. They need not be men with well-established reputations but they must be of high scientific calibre. It is on such men that the success or failure of long-range investigations will depend. The senior members of the staff must be given freedom from routine duties, adequate time to think and read, and a large measure of independence in choosing their lines of investigation. They should also have periodic opportunities to pay visits to centres of research in this country and abroad; they might well take some share in educational work by giving special lectures and taking part in open discussions on their subjects. Research cannot be conducted with success under airless conditions. Fresh currents of thought need to sweep through the laboratories from the outside world.

(v) Every Association whatever its background and whatever the

degree to which it has been in the habit of using science should have an efficient Information Bureau—an organisation which studies the current literature and imparts to its members up-to-date information about subjects which should interest them. If in a foreign language, the abstracts, intelligently translated, should be circulated to member firms. This is an essential function of all Associations and will form, if adequate, a not inexpensive item in the annual budget.

(vi) Liaison between the Association and its membership is of vital importance and can be secured in a variety of ways. First there should be a corps, as part of the staff of the Association, one or more members of which are not only conversant with the scientific work of the Association but familiar with works' practice. They must be good 'mixers': people who can talk the language of the foremen and operatives. On no account must they be 'superior' and academically-minded; for they must gain the attention and respect of men long versed in the practice of the industry. They should be able to interpret in simple language the meaning of the scientific results obtained in the central laboratories and the implications of them when applied to industrial processes. Such officers will win the confidence of the operatives who imagine they have forgotten more than a highbrow scientist is likely to learn. Especially must they secure the goodwill of the foremen. If the foreman is satisfied, it is probable that the men under him will listen.

(vii) Such a corps of scientific attachés deputed to pay visits to firms and explain results will not by itself furnish a complete liaison service. Arrangements should also be made for interchanges of staff. Firms might send promising new recruits to work for a while in their Research Association's laboratories and so acquire at an early stage acquaintance with the latest methods of scientific approach to industrial processes with which they will be intimately concerned. At that stage of their career their minds will be receptive and they would return to their factories with an outlook valuable both to themselves and their employers. Older men in the employment of member firms might also with advantage pay periodic visits of less, but appreciable, length to their Research Association in order to become familiar with the latest information and most up-to-date methods. Similarly, members of the staffs of Associations should be sent to member firms to work in their technical laboratories and so acquire first-hand knowledge of industrial problems. By such interchanges both the firms and the Associations would benefit and an additional means of training young industrial staff furnished.

(viii) Another means to the same end is to arrange for certain sections of the programme to be carried out in the works of a member firm, either by members of the staff of the Association alone or in collabora-

tion with the staff of the firm. This method has been employed with great success in more than one Association and has the great advantage of evaluating an investigation at every stage in the light of industrial practice and experience. Moreover, actual work on industrial plant by trained scientists may well lead to new conceptions and to further researches of importance.

(ix) A well-found Association with an adequate income must do still more than this. Between a laboratory result and its industrial expression there is a large gulf which must be bridged. It is probably true to say that the translation of what we may call a 'test tube' result into a form adapted for industrial use costs five to ten times that of the first discovery. It should be the business of a Research Association to proceed to this intermediate stage and present to its industry by means of a pilot plant something it can readily understand. The pilot plant should be devised and perfected in close collaboration between the originating minds and industrial engineers who can advise how particular difficulties can probably be surmounted. A Research Association is peculiarly well-fitted by its constitution to achieve this end and has immeasurably better opportunities than a Government laboratory confronted with the same problem. And what is equally, if not more, important the result will be more rapidly accepted by the industry.

(x) There are other fields of activity which might be entered if the Association were conducted on a sufficient scale. Subjects of economic importance to an industry might be studied. Questions of quality control, standardisation, factory layout, costing systems, and related subjects are all matters which can properly be regarded as falling within the ambit of a Research Association if the particular industry concerned thought it appropriate to charge its Association with such tasks.

(xi) All Associations should play a part in the advancement of technical education by collaboration with the educational authorities. With up-to-date knowledge of industrial technique and practice, the staff can make valuable suggestions in regard to syllabuses of instruction and arrange for courses of instruction both for teachers and senior students at the laboratories of the Association at times and seasons mutually convenient.

### *Finance of Research Associations*

Such an array of activities involves considerable financial resources; and the basis on which Research Associations have been financed from industrial sources in the past calls for careful study. Financial support has been secured by voluntary contributions on a basis proportionate to the size of the firm. Thus a small firm contributes less than a large firm and yet has the same privileges. The Associations have

adopted various methods of subscription, ranging from a voluntary basis with a fixed minimum to definite amounts based on a unit appropriate to the industry, e.g. capital, number of employees or wages paid. But these methods have not been universal and there are several instances where a federation or other trade group contributes a large annual sum and all its members thereby become members of the Association. In a few cases this substantial contribution is secured by means of a voluntary levy on the industry as a whole, and the contribution of a tenth of a penny per ton on output in the coal industry is the most substantial at present in existence.

Periodically during the last 25 years the idea of an 'Enabling Bill' has been mooted. By such a proposal a general Act would be put on the Statute Book under which an industry could demand the imposition of a compulsory levy for research by an Order in Council, provided the Board of Trade were satisfied that, say, two-thirds of the industry were in favour of it. If these powers were available and applied, the finance of an Association would be placed on a permanent and more equitable footing. Much time and labour at present devolves upon the executives of an Association in canvassing for additional income, and subscriptions are still often regarded by firms in the same light as contributions to some charitable object, instead of a wise insurance for future prosperity and therefore essential.

The idea of such an 'Enabling Bill' has been explored by consulting industry through their Research Associations; but there has never been sufficient support to warrant Government taking the necessary steps. The fear of Government control has been uppermost in the minds of the industrialists who have considered the question; and the same answer is likely to be given in the future, although most industrialists agree that the present system of voluntary subscriptions is unsatisfactory and inadequate. If, however, the Government put such a measure on the Statute Book by means of the necessary support in Parliament, industry as a whole would probably accept the measure with gratitude and would rapidly make use of its provisions by applying for Orders in Council. The matter has admitted difficulties.

Any such method would only supply a part, though the major part, of the industrial income required. There will always be 'user' elements wishing to participate in the operations of an Association. There will also be firms identified with an industry which have interest in the work of an entirely different Research Association from their own. A British railway may be much interested in the work of several Associations and certain large corporations with wide ramifications may wish to be conversant with what is being done in a dozen Research Associations.

*Leatherhead site*

A recent development of considerable interest has been the move on the part of several Research Associations, needing new and enlarged premises in the neighbourhood of London, to acquire sites on an estate at Leatherhead (*see* Appendix IV). By placing several Research Associations in close proximity to one another, mutual advantages can be secured and consultations can take place between members of the different staffs on scientific problems of common interest with an ease impossible by correspondence. One of the advantages of a university arises from informal discussions, often over a luncheon table, and similar opportunities will occur in this colony of scientific workers.

Pooling of library resources and common translation services should also be possibile economies, while a lecture hall and social meeting rooms should provide other facilities for the staffs.

# CHAPTER 33

# STATIONS OF THE DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

Another important section of the Advisory Council's policy was the fulfilment of the function laid down in the White Paper (see Appendix I) where they were charged to advise on proposals for establishing special institutions. The various Stations of the Department were set up under that direction. In this chapter the way in which the Stations came into being are described briefly with a summary statement of their work, if not dealt with elsewhere. Before doing this, it will be well to outline the general functions of the stations. They fall under one or more of the following heads:—

*Functions of Stations*

(i) The establishment and maintenance of scientific standards and constants, e.g. National Physical Laboratory.

(ii) National surveys of the country's natural resources, e.g. the coal fields by the Geological Survey, the chemical and physical survey of the national coal measures by the Fuel Research Board and the survey of the water resources of the country by the Geological Survey.

(iii) To serve as independent testing centres, e.g. the National Physical Laboratory, the Fuel Research Station, the Building Research Station.

(iv) To undertake industrial investigations of national importance which industry itself is unable or unwilling to undertake. In one or other aspect of their activities all the Stations fall under this head.

It is clear from this classification that the Stations are doing work of national importance, but there are certain limits to what is possible in the work undertaken under heading (iv). It is difficult, for instance, for a Government Station to erect and run pilot plants for new industrial processes, for these need the active co-operation of the industries' production personnel. Moreover the inability of industry to undertake some of the investigations made by certain Stations is disappearing as industrial research by the Research Associations is becoming better organised and more adequately supported by the firms. This steadily advancing change will need careful watching by the Department. Had the establishment of a Fuel Research Station come up for consideration in the present year, it is probable that much of its present work would have been entrusted to the British Coal Utilisation Research Association,

though certainly not the chemical and physical survey of the coal measures. It may well prove advisable to transfer to this, the largest of the Research Associations, the control of certain parts of the work of the Fuel Research Station and other sections to the Gas Research Board and British Coke Research Association. Whether similar arguments apply to other Stations under the Department will depend (1) on the extent to which any station is doing work of industrial as well as national importance, and (2) on the existence of a highly developed and financially sound Research Association capable of assuming full responsibility for the work. For the present a study of the Stations shows that their work is predominantly of national rather than sectional importance.

## THE NATIONAL PHYSICAL LABORATORY

While the Advisory Council was negotiating and consulting with the principal industries of the country about the founding of co-operative organisations for industrial research it recommended, where these proved impossible or unsuitable, the establishment of Research Stations directly administered by the Department. This second advance was supported and extended by the transfer, in 1918, of the financial responsibility for the National Physical Laboratory from the Royal Society to the Department and the acceptance of that Society's Executive Committee as a Committee of the Department.

The Laboratory was founded in 1900 for the purposes of carrying out research (especially research required for the accurate determination of physical constants), to establish and maintain precise standards of measurement, thus enabling British industry to keep pace with technical progress in other countries, and to test instruments and materials. It is divided into nine main Divisions: (1) Physics, (2) Light, (3) Electricity, (4) Radio, (5) Metrology, (6) Engineering, (7) Metallurgy, (8) Aerodynamics, (9) the Ship Division.

In the course of years the co-operation with the various Research Boards and Committees of the Department, the Research Associations and individual firms in industry has been greatly extended and developed. Some indication of the scope of the Divisions of the Laboratory is given in the following paragraphs:

1. The Physics Division is in three sections.

The *Heat and General Physics Section* deals mainly with the determination of the thermal properties of materials, for example, the thermal conductivity of materials used in furnace construction and in refrigerating plants. A recent research has enabled the temperature of liquid steel in open-hearth furnaces to be directly measured. The Inter-

national Temperature Scale is maintained in this section, covering the range from 180° C. to 3,500° C. and well over half a million thermometers and pyrometers of various types are tested annually. Work on the thermal properties of heat insulators has had great effect on the design of refrigerated stores.

The *Radiology Section* carries out researches on the measurement of X-ray intensity and dosage and on X-ray methods of crystal analysis and their industrial application. The structure of human teeth has been studied for the Medical Research Council. Measurements are made for hospitals, etc., of the protective value of materials used in constructing X-ray installations, and the X-ray departments of hospitals are inspected to ensure that adequate protection is afforded to operators. This work resulted in satisfactory international recommendations for protection. The section has charge of the British radium standard, and more than one-fifth of the estimated world supply of radium has been tested at the Laboratory.

The *Sound Section* has given much attention to problems of architectural acoustics. Help is given in the planning of new buildings to ensure good acoustic properties and existing buildings are examined with the aim of removing acoustic defects. Investigations on sound transmission through walls and floors have been carried out for the Ministry of Health with the object of ensuring good acoustics in large blocks of flats and this work has influenced building practice. Noise and its measurement have been studied and the reduction of noise has been effected in various industrial establishments, e.g. in aero-engine test houses. Work has been done for the Ministry of Transport with a view to reducing the noise of motor vehicles and limiting the noise of horns.

2. The LIGHT DIVISION was formed in 1940 by combining the Optics and Photometry Sections, which previously belonged to other Divisions:

The *Optics Section* studies the design of lens systems. It has done important work on the measurement of colour and on ultra-violet and infra-red spectrometry. It carries out tests of all classes of optical instruments, measures optical properties, such as refractive index, transparency and reflectivity, and tests photographic lenses and shutters.

The *Photometry Section* maintains the standard of light of the nation. It studies illumination problems, both of daylight and artificial light, relating to factories, offices, dwelling-houses, picture-galleries, etc. Ships' navigation lights and railway and road signal lights are tested. Street lighting has been extensively investigated for the Ministry of Transport. Methods of photo-electric photometry have been developed and introduced in this section.

The following are some of the results obtained in the Light Division in recent years: (i) The establishment of a scientific system of colori-

metry which has been internationally adopted. (ii) Investigations into lens theory have led to new methods of lens design. (iii) A standard scale of radiation has been established and radiometers for various purposes can be calibrated. (iv) Study of the behaviour of the eye under unusual lighting conditions has given invaluable guidance in determining the effective use of the eyes at night. (v) Study of daylight problems has led to the appreciation by architects of the importance of designing for daylight conditions and has provided them with the necessary data.

3. The ELECTRICITY DIVISION is in two sections:—

The *Electrical Standards Section* has charge of the British electrical standards, including the radio-frequency standards. Magnetic research and tests are also carried out.

The *Electrotechnics Section* is equipped with a high voltage installation capable of giving a voltage of one million volts at power frequencies and two million volts from an impulse generator. This plant has been used largely in connexion with the installation and maintenance of the grid electricity scheme of the country. Tests of electrical instruments and equipment of all kinds are undertaken—ammeters, voltmeters, wattmeters, fuses, circuit breakers, etc. Extensive researches have been carried out on cables.

The following are some of the results of the work in recent years: (i) Research on the heating of buried cables has had a profound effect on practice and resulted in large savings of money (*see* p. 45). (ii) Pioneer work on the surge testing of large grid transformers has ensured that they are reasonably proof against lightning. (iii) Important equipment has been designed which enables the properties of dielectrics at high temperatures to be determined.

4. The RADIO DIVISION has carried out an extensive programme of research for the Radio Research Board on wave propagation and on the nature and origin of atmospherics. The work on propagation includes study of the ionosphere and work on direction-finding and has resulted, in addition to its effects on radio-communication, in the provision of improved aids to marine and aerial navigation. The work on the ionosphere and its effect on radio-propagation led to the discovery of radio-location. Work on radio sounding balloons has been carried out for the Meteorological Office. The Division has experimental stations at Slough and Teddington.

5. The METROLOGY DIVISION is responsible for the standards of length, mass and time, and such derived standards as area, volume and density. Length standards of all kinds, including surveying tapes and wires, are

tested. Gauges of all kinds are tested in large numbers. Volume measurement includes the testing of volumetric glassware used for chemical analysis. Hydrometers are also tested. In the section dealing with the measurement of mass, weights and balances are tested and densities determined. The taximeters working in London are checked annually for the police. Diffraction gratings are ruled in this Division. Among the researches of the Division may be mentioned one which has made it possible to use a wavelength of light as the ultimate standard of length, thus establishing it on a fundamental physical basis. An accurate determination of the acceleration due to gravity has been made and an extensive study of the pivots and jewels used in instruments has been carried out.

The development of instruments for rapid and accurate gauging and the measurement of very large numbers of industrial gauges at the Laboratory have been of great value to the precision engineering industries. Work on methods of measuring gears and hobs has led to great improvements in the efficiency of gears.

6. The Engineering Division has carried out important work on the strength of materials. The lengthy researches on the 'fatigue' of metals and on the behaviour of metals at high temperatures may be instanced. Work on the effect of surface conditions and stress concentrations on the fatigue of steels has enabled the fatigue stresses to which steels may be subjected to be increased by appropriate treatment (machining and shot blasting). Research on the manner of deformation of metals at high temperatures has led to the introduction of alloys with improved properties at high temperatures. In the earlier days of this Division, pioneer work was done on fluid flow which has had a great effect on the study of aerodynamics. Another aspect concerns the effect of wind pressure on buildings. This has led to adequate provision being made for it in building structural design. Other investigations have dealt with welded structures and road improvement. Engineering tests of all kinds are carried out in the Division.

7. The Metallurgy Division has for many years studied intensively aluminium and magnesium alloys. The introduction of these alloys for aircraft construction some 25 years ago was largely due to the work of the Division. The constitutional diagrams of many systems of alloys, both ferrous and non-ferrous, have been accurately determined. Other researches which may be briefly mentioned have dealt with: the production of pure metals (e.g. iron of 99·985 per cent purity), gases in steel, aluminium alloy castings and their age-hardening, refractory materials for high temperatures, dental alloys and the cracking of boiler plates. The Division possesses a foundry and rolling mill for work on a semi-industrial scale.

8. The AERODYNAMICS DIVISION carries out investigatory work under the control of the Aeronautical Research Committee of the Air Ministry, (*see* p. 296). It is equipped with twelve large wind tunnels and whirling arm for experiments on models of aircraft. In one tunnel the air circulates past the model at a pressure of 25 atmospheres, thereby eliminating scale effect. There are also high speed tunnels capable of air-speeds up to 600 miles per hour. The researches carried out in the Division, in conjunction with full-scale work elsewhere, have contributed much towards the rapid development of aerodynamics in this country. Work has been done on all types of machines and on their component parts, as well as on aeroplane carriers, airships, parachutes, etc.

Amongst the results are: (i) A theoretical and experimental investigation of the flutter of aircraft members laid the foundation on which all flutter preventive measures have been based. (ii) The study of fluid motion has contributed greatly to the determination of the best shapes for aircraft bodies, wings, etc. and has enabled full-scale results to be predicted from model tests. (iii) Important results have been obtained in the investigation of stability and control; this subject concerns the correct proportioning of wing and tail surfaces so that an aeroplane returns to the original flight condition if disturbed, and the design of control surfaces for use in manoeuvring. The subject includes the study of spinning, which was first closely studied at the Laboratory with success. (iv) In the testing of models of proposed aircraft designs performance estimates are checked, adequate stability and control are ensured and unsatisfactory features are remedied. An interesting case was the work on the seaplanes used in the Schneider Trophy races, from which machines the conception of the Spitfire followed.

9. The SHIP DIVISION—until recently called the William Froude Laboratory—consists of two tanks for testing ship models, the larger being 678 ft. long and 20 ft. wide. Some 90 ships have been tested in a year and, as a result of the tests, the efficiency of the ships is not infrequently improved by over 10 per cent, and in certain cases by as much as 30 per cent. All types of vessels are tested—from Atlantic liners to herring drifters. A programme of ship research is also carried out, and among the subjects on which papers have been published are the effect of hull-form on ship resistance and propulsion, the behaviour of ships in heavy seas, design of propellers, manoeuvring and the wind resistance of ships' superstructures. The Division is also equipped with a continuous-flow tunnel for the study of propeller cavitation.

The main objective of the Laboratory is to afford assistance to British industry and inquiries from industrial firms faced by technical difficulties are welcomed. Frequently the experience of the Laboratory

enables problems to be solved without recourse to experimental work, but where tests or investigations are necessary, a programme is suggested and fees are quoted. The results of the researches carried out are published in the journals and transactions of the scientific and technical societies.

## THE GEOLOGICAL SURVEY AND THE MUSEUM OF PRACTICAL GEOLOGY

The Geological Survey originated in 1835 from a proposal of the Ordnance Survey to combine a geological examination of the English counties with the geographical survey then in progress. The proposal was adopted by the Government who made a grant to defray the expenses of colouring geologically the Ordnance county maps. Henry Thomas de la Bêche, at that time Foreign Secretary and subsequently President of the Geological Society, became the first Director of the Geological Survey in 1835 and work was begun in Devon and Cornwall. At the same time it was suggested by de la Bêche that, with the establishment of the Geological Survey, means now existed of collecting 'specimens of the applications of geology to the useful purposes of life', and the Museum of Economic Geology was founded in 1837 at No. 1 Craig's Court, Charing Cross and opened to the public in 1841. The Geological Survey was separated from the Ordnance Survey in 1845 and placed with the Museum of Practical Geology, as it was thereafter called, under the Office of Woods and Forests. In 1851 the two institutions were transferred to a new building in Jermyn Street and in 1853 were put under the control of the Department of Science and Art, established under the Board of Trade in 1851 and eventually incorporated in the Board of Education which was set up under the Board of Education Act, 1899. In 1919 the Survey and Museum were both transferred to the Department of Scientific and Industrial Research and in 1935, the centenary year of the Survey, they were moved to a new and better building in Exhibition Road, South Kensington.

The normal work of the Geological Survey is the continuous survey, re-survey and revision of the geology of Great Britain and the preparation and publication of geological maps and memoirs of the areas surveyed. From its inception the Survey, concerned as it is with a highly industrialised and densely populated country, has paid special attention to the economic aspects of geology and coalfield work. Begun in 1839 under de la Bêche and stimulated from time to time by Royal Commissions on Coal, these aspects have remained in the forefront of its activities ever since. Economic minerals and rocks other than coal are dealt with in a series of special memoirs and reports and the important subject of water-supply and resources, which formed a feature of the earliest publications

of the Survey, has developed with the increase in industrialisation into a permanent and growing part of Survey activity. Special memoirs dealing with the water-supply of various districts have been published since 1902. In addition to the maps of the 'solid' geology of the country, the Survey also publishes 'drift' maps showing the distribution of the superficial deposits. These are of special interest to agriculturists and the Survey in this branch of its work is in the closest co-operation with those engaged on soil-surveys and investigations. Two special soil-texture maps of North and South Ayrshire have been published.

Under the provisions of the Petroleum Production Act, 1918, and the Mining Industry Act, 1926, notification of intended borings must be given to the Geological Survey with full liberty of access and the right to obtain a complete record of the geology of the bore. Prior to 1918 the Survey with the co-operation and goodwill of the interests concerned had collected a large mass of boring-records and data, but the statutory responsibilities of these Acts have greatly increased the work of the boring-records department.

The records and specimens of the Geological Survey have from its inception been housed in the Library and the Museum of Practical Geology where they are available for all bodies and persons interested. The Library, which is open to the public, also contains a comprehensive series of foreign geological maps and publications. The exhibits in the Museum illustrate the general principles of geology, the regional geology and scenery of Great Britain and, in addition, comprise valuable displays of economic minerals and rocks from all parts of the world. Apart from the galleries open to the public there are large reserve and study collections available for students and specialists. The exhibited minerals are arranged topographically and according to their economic uses, and the fossils are arranged stratigraphically and not as in the British Museum, biologically.

There is a branch of the Survey in Scotland with its headquarters in Edinburgh where the Royal Scottish Museum devotes a section to the exhibition of material illustrating the work of the Survey in Scotland.

## THE FUEL RESEARCH STATION

Early in 1916 the Advisory Council had begun the study of problems of fuel. A number of applications for grant had been received from professional societies and university workers. The Reconstruction Committee of the Cabinet had appointed a Sub-Committee on Coal Conservation and a Committee of the British Association to promote fuel economy had applied for a grant. Consultations with these bodies led to the appointment of a Fuel Research Board in 1917 by the

Committee of Council with Sir George Beilby as Director. The Board advised the establishment of a Fuel Research Station and in 1918 the necessary buildings were provided at East Greenwich.

An important section of the Fuel Research Board's work, related to that of the Geological Survey, deals with the chemical and physical survey of the coal seams of the country. This survey receives the co-operation of the industry through a number of local committees in the various coalfields. Nine local laboratories have been provided in which the chemical and physical analyses are made. Part of the survey is conducted at the Fuel Research Station which also co-ordinates the work of the local laboratories. Recently the importance of a study not only of the coal and other minerals in the seams, but also of minor elements such as germanium and vanadium in the ash of the coal itself has been emphasised. A survey is now in progress with a view to a quantitative estimate of coal reserves of the different types available to meet the various industrial and domestic requirements. The Coal Commission and the Geological Survey are co-operating.

The safe and efficient storage of coal, 'dust-proofing', and coal-cleaning have also been studied and experiments on the use of pulverised coal and the design of burners conducted. Tests with a full scale commercial plant of vertical gas retorts as early as 1920–21, a technique then comparatively new, proved of value to the industry. Later work in collaboration with the gas industry proved that the flexibility of existing carbonisation processes in treating coals of different types could be increased. Work has been done on carbonisation in coke ovens, on the water gas process, and on the complete gasification of coal. The Department in 1924 secured an option on the German Bergius process for the hydrogenation of brown coal. This led to a continued study of the hydrogenation of coal and of low-temperature tar with ancillary investigations. In 1934 the study of the Fischer-Tropsch process was begun and is still in progress. Many other investigations ranging from the use of different fuels for domestic use and for internal combustion engines have been made (see also pp. 31–37).

## THE FOOD RESEARCH STATIONS

In the autumn of 1917 the Lord President appointed a Cold Storage Research Board which in 1918 became the Food Investigation Board, with Mr. W. B. (later Sir William) Hardy, as its Chairman and as the first Director of Food Investigation. The terms of reference of the Board, as adjusted in 1919, were: 'To organise and control research into the preparation and preservation of food.' Special emphasis was placed on the preservation of fresh foods by refrigeration, the import-

ance of which had been pressed on the Department by a deputation from the Cold Storage and Ice Association in June 1917. The work expanded rapidly and in 1919 approval was given for the erection of a laboratory at Cambridge for 'fundamental scientific research in biochemistry and biophysics at low temperatures'. A site was provided by the University, which was also associated with the Department in a committee of management. The laboratory, known as the Low Temperature Research Station, was completed in 1922.

The early work of the Food Investigation Board was devoted largely to an attack upon three major practical problems—the preservation of homegrown fruit, particularly apples, the overseas transport of beef over great distances in the chilled (as distinct from the frozen) condition, and the handling and preservation of fish. These problems have, in the main, been solved successfully. An important factor in this success was the realisation, for which the Board and the country are indebted to the insight and leadership of the late Sir William Hardy, that fundamental biological research is of the first importance in relation to the preservation of foods.

In 1929 a separate station for the investigation of scientific problems in the handling and preservation of fish was established at Aberdeen, as the Torry Research Station. Investigations at this laboratory have dealt mainly with the freezing and the smoking of fish, and the fundamental biological problems involved.

The Low Temperature Research Station was enlarged in 1929, and shortly afterwards a new station (the Ditton Laboratory) for larger-scale experimental work on the storage of fruits was opened in Kent, in close proximity to the Horticultural Research Station at East Malling.

In 1935 the Department took over from the Ministry of Agriculture the responsibility for Government assistance to the Chipping Campden Research Station of the University of Bristol, where pioneer work had been carried out on the canning of fruit and vegetables.

It was also found advisable to establish a small laboratory for fruit examination and related experimental work in the neighbourhood of the Covent Garden fruit and vegetable market. This laboratory started its work in 1926. The idea of a small laboratory in immediate contact with a large wholesale market proved a useful one, and in 1938 arrangements were made to open a similar laboratory, adjacent to the Smithfield market, for work in connexion with meat (see also pp. 235–239).

## THE BUILDING RESEARCH STATION

In June 1917 the Local Government Board asked the Department to undertake researches into the suitability of a number of building

materials and methods of construction for cottages. Accordingly a Building Materials Research Committee was appointed to arrange for work in that field, into whose scope were also brought certain researches on heating and ventilation and on fire prevention which were already being conducted with the help of the Department by the Institution of Heating and Ventilating Engineers and the Fire Prevention Committee respectively. The Building Materials Research Committee was superseded in 1920 by the appointment of a Building (Materials and Construction) Research Board to co-ordinate and supervise the wider range of investigation which the Department was then being called upon to undertake by the Ministry of Health which had replaced the earlier Local Government Board. In July 1921 the Research Board established a small station at East Acton and they built a number of experimental cottages at Amesbury. When the Board had been set up the question of its continuance after an experimental period was reserved for further review. In 1924 it was decided to continue the work of the Board for another five years at least and in 1925 a request came from the Ministry of Health that the Department should 'undertake on a more comprehensive scale investigations directed to problems arising out of the present housing difficulties'. For this the temporary hutments at East Acton were inadequate and accordingly a house standing in ample grounds was secured at Garston, near Watford, which could be rapidly and cheaply adapted for the required purpose and additional buildings erected. Here the Research Station has since been located. It is noteworthy that both the inception of building research and its continued development was due to the national need for a housing programme towards the end of, and in the years following, World War I. The absence of any provision in the industry itself for the application of science either in its general progress or to the social problems to which the war had given rise was a determining factor.

From the many problems involved in the satisfactory building of houses the Station proceeded to the functional requirements of buildings whatever their purpose. In a sentence the general object of all the work done, whether on materials, structures, foundations, insulation against sound or temperature changes has been to develop a science of building (see also pp. 189–194).

## THE FOREST PRODUCTS RESEARCH LABORATORY

In 1921 on instructions from the Government the Lord President appointed, after report from the Advisory Council, a Forest Products Research Board for investigations into timbers and other forest pro-

ducts from home and overseas supplies. This development was undoubtedly due, like the founding of the Building Research Station, to the needs of the national housing movement in the first place. After making a full survey of its field of work and, after securing through the Department as an urgent matter a timber-seasoning plant at Farnborough, the Board submitted plans for a Forest Products Laboratory. The Department obtained a site for the Station at Princes Risborough, and the work was placed under Mr. R. S. (later Sir Ralph) Pearson, as Director, who had been the head of the Forest Products Section of the Forestry Research Institute at Dehra Dun. The station at Farnborough was temporarily extended and extra-mural investigations conducted at the Imperial College, at Oxford and St. Andrews. In July 1927 the staff and plant of the Board were transferred to the new laboratories at Princes Risborough, while the extra-mural work at Oxford, at the Imperial College and St. Andrews was continued. The arguments for a national approach to forest products research are similar to those involved in building.

Besides a study of the many problems affecting the general use of timber such as seasoning, physical properties of home grown and foreign timbers, insect infestation and the design of wood-working tools and machinery, the Station has dealt with the utilisation of waste wood and the suitability of new woods for the manufacture of plywood. It has also investigated questions of timber economy and preservation as they affect the building industry and improvements in the use of plywood for aircraft and boat-building. Preservation and selection of timber for the railways, the mines, and agriculture, and for a number of minor industries have also found a place, as well as the design of containers for packaging (see also pp. 194–5).

## THE RADIO RESEARCH STATIONS

In 1919 as the result of representations made to the Department by the Imperial Communications Committee of the Cabinet, a Radio Research Board had been established under the chairmanship of Admiral of the Fleet Sir Henry Jackson, F.R.S. 'to co-ordinate the work of the various Government technical establishments and to make arrangements to meet the requirements of Government Departments and others for research not otherwise adequately provided for'. After some of its work had been entrusted to the National Physical Laboratory and to the Aldershot Wireless Station of the Meteorological Office, a site at the Compass Observatory, Ditton Park, near Slough, was provided by the Admiralty for the work of the Board on directional wireless. A station was also established at Aldershot for researches into the funda-

mental nature of atmospherics but this was subsequently moved to the Ditton Park site which became known as the Radio Research Station, Slough. In connexion with Professor E. V. (later Sir Edward) Appleton's researches into the effects of ionisation of the atmosphere on wave propagation the Board took over in 1925 the Post Office's Experimental Station at Peterborough. In 1933 the work of the Radio Research Board, which had been so far chiefly divided between the National Physical Laboratory and the Station at Slough, was largely concentrated at Teddington, though still under the control of the Board, and partly at the Research Stations at Slough and Leuchars which were retained. During the years active co-operation with the Dominions Governments has continuously increased.

## THE CHEMICAL RESEARCH LABORATORY

The Chemistry Research Board was first established in 1922 as one of four co-ordinating Boards set up by direction of the Government to co-ordinate, in the interest of economy, work of value to the Fighting Services but also to deal with industrial applications. The four Boards were soon approached by various civil departments for advice and help in work of importance to their administration. The Chemistry Research Board was asked by the Home Office to assist in discovering alternative disinfectants to formaldehyde for treating wool and hair, and the Ministry of Health asked for advice in the disinfection of shops. These and other researches had involved difficulties arising from the lack of laboratory facilities. The Services were less supplied with them than with laboratories for metallurgy, physics and engineering. Accordingly sanction was obtained in 1923 for the erection of a chemical laboratory on land that had been bought by the Treasury adjacent to the National Physical Laboratory. Thus the Chemical Research Station came into existence in 1925 with Professor G. T. (later Sir Gilbert) Morgan, professor of chemistry at Birmingham University, as its superintendent. Special attention was devoted to chemical reactions at high temperatures and pressures in the application of which remarkable industrial successes had been obtained abroad. The Board aimed at developing the technique and establishing the scientific data for reactions of this kind, in the interest primarily of Government requirements and particularly to explore industrial problems of special importance to national defence.

## WATER POLLUTION RESEARCH LABORATORY

As a result of proposals made by the Ministry of Health and the Department of Agriculture and Fisheries a Water Pollution Research

Board was appointed in 1927 under the chairmanship of Sir Robert Robertson, then Government Chemist. The presence of sewage in our rivers accounted, it was estimated, for 70 per cent of the damage to fisheries and the domestic consumption of water had increased so greatly in recent years that recourse to many rivers hitherto considered unsuitable as sources of additional supplies was probable in the near future. The purification of trade effluents, and especially those of the beet sugar industry and those from dairies and milk products factories was of great importance. An early inquiry was a biological and chemical survey of the river Tees as many types of effluent were discharged into it, and in 1927 experiments were begun into the waste water from beet sugar factories. Investigations were also made for the Board by the Chemical Research Laboratory into the base-exchange process of water softening, by the London School of Hygiene, into the biological aspects of activated sludge, and by University College, London into the colloids in sewage.

In 1933 an investigation of the effects of the discharge of crude sewage into the estuary of the river Mersey was begun. Its object was to determine the effect of the discharge on the amount and nature of the silt and other solid matter deposited in the estuary. In order to maintain navigable channels the Mersey Dock and Harbour Board have to conduct constant dredging in which the Merseyside local authorities are also interested and it has been found that the operations are seriously hindered by the nature of the silt in certain reaches of the river. The investigation has called for a very wide range of inquiry and experiment and is the classic example of the researches which would be needed in a similar study of other contaminated rivers and tidal basins. For that reason it is worth noting the procedure adopted. The quantities of fresh water carried by rivers and streams feeding the estuary had to be estimated as well as the volume of sewage discharged. From these and an analysis of samples of the water, an estimate of the concentration of sewage at different points had to be made. The sources of mud and clay deposited were surveyed, examined and compared with samples from the bed of the sea and from other relatively unpolluted estuaries of the country. Laboratory experiments were made on the rates of sedimentation of mud and clay from their suspensions in sea water, estuary water, tap water and mixtures of sea and tap water. In addition the records of hydrographic surveys at various times from 1861 to 1935 were examined, calculations made to show the changes in the quantities of water carried into and out of the estuary during tides of different ranges, and systematic measurements made of the velocity of the flow of those tides. The records of dredgings in the estuary and in Liverpool Bay over many years were also examined.

It was concluded that the crude sewage discharged into the estuary had no appreciable effect on the amount and hardness of the deposits in the estuary.

*Beet sugar effluents*

During the years 1927 to 1930 experiments on the treatment of waste waters from beet sugar factories were made for the Board by the Rothamsted Experimental Station both on a laboratory and a semi-commercial scale. The conclusions reached were briefly that the large volumes of fluming and washing waters can be re-used after sedimentation of the soil washed from the beet. Waste water from the condensers of the evaporators can also be re-used after cooling and any necessary treatment to prevent growth of organisms. The most polluting waters are those from the diffusers and from the pressing of the cossettes. These, or a large part, can be re-used in diffusers of the continuous type. In battery-type diffusers it is more difficult. It may be necessary to discharge part of the liquor from time to time but the waste waters can be treated after dilution in percolating filters of the kind used in sewage disposal works. Most of the factories situated on rivers re-use a large part of their waste waters.

*Effluents from dairies and milk products factories*

In 1941 the results were published of a full investigation of the treatment of waste waters from the milk industry. This investigation was made for the Board by the Rothamsted Experimental Station. The research showed that considerable reduction in strength of the waste waters can often be made by simple modifications in the factory processes and by careful supervision. The remainder can be satisfactorily treated either by the activated sludge process or by the method of 'alternating double filtration' which is easier to control than the activated sludge method and less easily upset by changes in the volume and strength of the waste waters. Plants of the alternating double filtration type have been installed at a number of dairies and milk products factories with satisfactory results.

A temporary laboratory for the work of the Board was obtained at Watford in 1939.

## THE ROAD RESEARCH LABORATORY

In 1932 the House of Commons Select Committee on National Expenditure recommended that the research on roads then in the hands of the Ministry of Transport should be transferred to the Department of Scientific and Industrial Research. Accordingly a Road Research Board

was appointed, with Mr. F. C. (later Sir Frederick) Cook as chairman, and the experimental station of the Ministry of Transport at Harmondsworth became the Road Research Laboratory of the Department. Its activities were gradually expanded and the laboratory was enlarged but considerable sections of work have been entrusted to the National Physical Laboratory, the Building Research Station and the Chemical Research Laboratory. It continued to be concerned primarily with materials and methods of construction. The wider problems (such as planning, layout, economics and road safety) have not yet been made the subject of organised scientific work, though at the beginning of World War II there were tendencies in these directions.

After 1933 the Ministry of Transport continued with their full-scale experimental work on roads. They have considered many technical problems, chiefly by means of committees, and the British Standards Institution has participated widely in preparing standards. In addition many local authority engineers have been responsible, individually, for technical improvements, and private industry has co-operated actively with Government. All the main materials used in road construction have been improved in one way or another by private enterprise. Outstanding examples are tar and asphalt, traffic markings, signalling systems and street lighting. An analysis of the many problems of road research is given on pp. 231–3.

# CHAPTER 34

# OTHER GOVERNMENT STATIONS FOR CIVILIAN RESEARCH

The remaining Government organs for civilian research in order of their foundation are (i) the Government Chemist; (ii) the Medical Research Council; (iii) the Agricultural Research Council, and (iv) the General Post Office.

## THE GOVERNMENT CHEMIST

The Government Chemist is the head of the Department bearing his title which is a Department of State with a separate Vote. The Government Laboratory was established in 1842 as the Excise Laboratory to detect at first adulteration of tobacco, and later of all dutiable articles. Subsequently, other Departments called upon the services of the Laboratory, so that it became a separate Department in 1911 with a view to meeting the needs of all Departments of State for chemical analyses. The Government Chemist is the referee under the Food and Drugs Act and *ex officio* the Chief Agricultural Analyst under the Fertilisers and Feeding Stuffs Act 1926. Advice is given on all chemical matters to Government Departments directly charged with duties under Acts of Parliament. Investigations and research are carried out for Departments, particularly in connexion with the Committees set up to investigate problems of analysis. The day-to-day work of the Laboratory comprises the analysis of a great variety of materials of which in the year 1939 some 550,000 were examined.

In the decade following its establishment as a separate Department new work came mainly from the non-revenue departments. At the request of the Director of the Geological Survey and Museum, the chemical work of the Survey was taken over in 1913. During World War I much additional work was undertaken for the Admiralty, War Office, Air Ministry, Ministry of Munitions and the War Trade Department. This work involved research into methods of analysis suitable for the special requirements of the various departments and in this connexion the analytical use of ultra-violet absorption spectra of alkaloids and of light elements was examined.

After 1921 a number of investigations of general interest to the public were undertaken at the instance of various Government Departments: the carriage of dangerous goods by sea, atmospheric pollution, the possible danger to health arising from the use of lead tetra-ethyl in

motor spirit, and the suitability of photography for copying documents. In addition, investigations of a different character included the recovery of radium from decayed luminous indicators, the determination of helium in natural gas, and the production of potash salts from Dead Sea water and Indian brines. Research on the infra-red spectra of many substances, including the diamond, led to the discovery of two 'types' of diamond.

## MEDICAL RESEARCH COUNCIL

Under the National Health Insurance Act (1911) financial provision for medical research was first made by Government. In 1913 a Medical Research Committee, empowered to prepare and conduct schemes of research, was set up under the Act by the Insurance Commissioners for England, Wales, Scotland and Ireland. The Medical Research Committee could initiate schemes of research, and when they had been approved by the responsible Minister had full executive control in carrying them out. Under the Ministry of Health Act (1919) the responsibility was transferred to a special Committee of the Privy Council, with the Lord President as Chairman, and the Minister of Health as Vice-Chairman. The latter Minister had a general responsibility under the Act for the initiation and direction of research, and the Ministry has retained and increased the short-range research and intelligence work needed for its own purposes.

Under the Committee of the Privy Council, the Medical Research Council was established in 1920 and incorporated by Royal Charter. It has twelve members: nine appointed in respect of their scientific qualifications, and of the others one must be a member of the House of Commons and one a member of the House of Lords. Vacancies are filled by the Committee of the Privy Council, but in the case of the nine scientific members this is done after consultation with the Medical Research Council and with the President of the Royal Society. The Council has full executive responsibility, controlling all its own work and appointing its own officers. The work is financed, not under a separate Vote in Parliament, as is the case with the Department of Scientific and Industrial Research, but by a grant-in-aid under the Vote for Scientific Investigation in the Civil Estimates.

The Council maintains, as its central establishment, the National Institutes for Medical Research at Hampstead and Mill Hill and various research units attached to other institutions: it also assists work at universities, hospitals and elsewhere by means of grants for specific researches. It co-operates with the Government Departments interested in medical questions, including the Colonial Office in respect of research

in tropical medicine, and with bodies fulfilling functions like its own in the Dominions and in India.

Part of the Council's work lies in the fields of industrial medicine, industrial physiology and industrial psychology. The Council maintains as part of its own organisation, a department for research in industrial medicine at the London Hospital, a unit for research in applied psychology in the University of Cambridge, and a group of workers in industrial physiology attached to the London School of Hygiene and Tropical Medicine. In these subjects the Council is advised and assisted by the Industrial Health Research Board. This body (originally called the Industrial Fatigue Research Board) was established in 1918, in effect a successor to the Health of Munition Workers' Committee: it was appointed in the first instance jointly by the Medical Research Committee and the Department of Scientific and Industrial Research, and came under the sole direction of the Council in 1921.

## AGRICULTURAL RESEARCH COUNCIL

The Agricultural Research Council was established by Royal Charter in 1931. It is responsible to the Privy Council Committee for Agricultural Research of which the Lord President is Chairman. The Council is entrusted with the scientific oversight of all agricultural research in Great Britain and is responsible for ensuring that the organisation for research is maintained at a high level of scientific efficiency. It acts as adviser to the Agricultural Departments and to the Development Commission in regard to the estimates and programmes of the Agricultural Research Institutes in Great Britain which exceed twenty in number. Provision for the Council's work is made by an annual grant-in-aid under the Vote for Scientific Investigation in the Civil Estimates. The Council is free to spend this grant-in-aid at its own discretion and to undertake research either in institutes of its own or elsewhere.

Research in Agricultural Engineering is carried out by the National Institute of Agricultural Engineering at Askham Bryan, near York, maintained by the Ministry of Agriculture and Fisheries. In matters concerning the management of the Institute, the Ministry is advised by the Agricultural Machinery Development Board which was appointed in 1942.

General co-ordination between the Medical Research Council, the Agricultural Research Council and the Department of Scientific and Industrial Research on border line questions is secured by the appointment of Assessors to the Advisory Council of D.S.I.R. (*see* p. 256 above), and by regular periodic conferences of the Secretaries of the three organisations.

## GENERAL POST OFFICE RESEARCH LABORATORY

Industrial research activities by the Post Office on an organised basis were inaugurated in 1904 to enable full advantage to be taken of the many developments in physical science which could be usefully applied to telecommunications. The Post Office both initiates developments and investigates the application of those originated elsewhere. The total staff engaged on research and on engineering problems approaches 1,000. Originating in a few odd laboratories in the City the main group of research workers was installed on a site at Dollis Hill in 1921. The present permanent buildings were formally opened in 1933 and include fully equipped laboratories for carrying out investigations in telecommunications together with workshop facilities for the construction of apparatus in course of development.

A prime function of research in the Post Office is the investigation of special problems arising in the day-to-day operation of the telephone, telegraph and radio services. Its more important work, however, is scientific investigation and engineering experiment leading to the evolution of new types of plant. As indicative of this type of work, the recent development and utilisation of systems of multi-channel telephony may be mentioned. As a result of this work the Post Office is now using a system capable of handling simultaneously 600 separate conversations on a single circuit. The latest advance in this connexion, and one which may enable the number of circuits operated over a submarine cable to be greatly increased, is the design and construction of a repeater or amplifier for insertion in submarine cables. The repeater recently inserted in a cable in the Irish Sea is the first of this type to be put into service anywhere in the world. Other problems associated with the transmission of speech over long distances which have been solved were concerned with the suppression of electrical echoes and the maintenance of the stability of a circuit (*see* p. 208).

The radio services operated by the Post Office are of considerable importance and demand an increasing application of experimental work. For the overseas radio telephone services, inaugurated with the transatlantic telephone in 1927, special sending, receiving and terminal equipment has had to be produced. Activities in recent years culminated in the successful use of single sideband systems for the American service. This work had necessitated special investigations in the use of quartz crystals of high precision for filters and oscillators, and in the absence at that time of any source of such articles in this country it became necessary to set up a small unit to study the technique and to produce the required high-stability crystals. This unit has proved to be of great

value in connexion with later line and radio developments; the latest previous to World War II was the successful adoption of ray-diversity working on the American service which required among other things the designing and construction of an 1,100 valve receiver.

Another important work has been the application of unattended ultra short wave radio services to link up the ordinary trunk services to islands round Great Britain. Later systems handle a plurality of conversations on a single radio service. A recent advance has been the application of frequency modulation to these multichannel services.

The Post Office engineers have taken a foremost part in devising means enabling a trunk operator, by automatic switches operated over the long distance line, to complete the setting up of a call to a subscriber in a distant centre without the assistance of other operators. Their research in acoustics has been responsible for improvement of the subscriber's microphone and receiver.

The Post Office engineers have for many years emphasised the importance of overall transmission standards covering instruments and lines. The research laboratories are responsible for the maintenance of national standards of transmission and several foreign administrations have been supplied with standards calibrated against the national standard.

Certain groups of workers are concerned with the study of materials. Modern methods of examination, e.g. spectrographic analysis and structure-determinations by electron diffraction, have been introduced for the study of technical problems. Fundamental investigations of properties of interest to the engineering industry generally (e.g. many relating to dielectric phenomena) have not usually to be carried out by the Post Office as the information is available from the researches of such bodies as the National Physical Laboratory. There are, however, frequent gaps in the information on telecommunication plant. Since the beginning of World War II valuable work has been done on substitute materials to replace those in short supply. At the beginning of the war mechanisation of letter and parcel sorting was being studied. Various devices had been worked out involving the application of photoelectric cells and such like modern electronic equipment. These will, it is anticipated, facilitate the handling of letters and parcels in the post-war period.

# CHAPTER 35

# RESEARCH FOR THE SERVICES

Besides the research stations for civilian purposes, the Fighting Services also have their own research organisations for defence, referred to below.

## THE NAVY

In 1920 a Director of Scientific Research was appointed by the Admiralty. Before World War I there was no scientific research department. The Director is responsible to the Controller of the Navy for (*a*) the general direction and organisation of research work for naval purposes; (*b*) advising as to the programmes of research and as to proposals for specific investigations; and (*c*) the efficiency of the organisation for research and experimental purposes of the Admiralty Research Laboratory. He is not responsible for large scale experiment and trial nor for the allocation of funds for the Research Department, Woolwich, nor for proof and experiment at Shoeburyness. In general the Director is responsible for bringing about the close association of civilian scientists with the research and development work undertaken by the other technical departments of the Admiralty.

The Admiralty Research Laboratory at Teddington is the only establishment under the control of the Director. It is staffed wholly by civilians and deals with research of a fundamental and pioneer nature which may bear on naval interests and for which no appropriate outside agency exists. The Admiralty recently announced the formation of a Royal Naval Scientific Service to make permanent provision for the Navy's needs 'in the fields of research, experimental design, and development'. The new service will be staffed by those now forming the administrative, scientific, technical and chemical pools working under the Director of Scientific Research who is to be the head of the new service.

## THE ARMY

In 1938 the War Office appointed a Director of Scientific Research, and under the Ministry of Supply Act, 1939, and the Ministry of Supply (Transfer of Powers) (No. 1) Order, 1939, the Minister of Supply took over—among other responsibilities—from the Secretary of State for War and the Army Council, all design, inspection, research and experi-

mental facilities (Establishments, Staff, etc.). In that transfer the Army's Director of Scientific Research was included. The Ministry of Supply undertakes all research, development, design, etc. for Army Stores. Although the Army is still the principal 'user', a great volume of work is carried out for the other Services and Government Departments. But the contacts and relations between the Ministry of Supply and the War Office continue to be close.

Since the transfer in 1939 a considerable number of changes have taken place in the control of research and development, etc. The present position is as follows: Research, development and design of weapons and equipment is carried out on behalf of the War Office by the Ministry of Supply. The Ministry of Supply also carries out a considerable amount of inter-service research and development. Thus the Armaments Research and Design Departments do work on behalf of all three Services and the same is true of the Chemical Defence and Rocket development divisions.

Responsibility for research and development in the Ministry of Supply, which is carried out in some 18 establishments and extramurally, in industry, in universities and elsewhere, is vested in three senior officials.

(1) The Controller General of Munitions Production (C.G.M.P.) is responsible for research and development other than that under the Chairman of the Armoured Fighting Vehicles Division (see below). He operates through the Director General of Scientific Research and Development who is responsible to C.G.M.P. for the following fields: Chemical Defence including Smoke; Chemical Research and Development; Physical Research and Signals Development (including radar and radio); Rockets; the Technical Application of Metals; Advisory Service on Welding.

The Director General of Scientific Research and Development is also Chief Scientific Adviser to the Ministry, Executive Officer of the Minister's Advisory Council for Scientific Research and Technical Development and Chief Officer of the Staff for Scientific Research.

The Scientific Advisory Council includes senior officials of the Ministry and other Supply Ministries, and of the Department of Scientific and Industrial Research together with independent scientists. It operates through 17 scientific and technical committees with appropriate sub-committees and panels, each including both official and outside scientific members. A similar function is performed in the field of Chemical Warfare by means of the Chemical Board, which is linked up with the Scientific Advisory Council.

(2) The Senior Supply Officer (S.S.O.) is responsible for the administration of the Armaments Design Department, the Armaments Research

Department and the Ordnance Board. The ordering authorities on behalf of the Services formulate the programme of work of these Departments and approve the results. An inter-Services Committee, known as the Armament Development Board, of which the Senior Supply Officer is Chairman, studies armaments research, design and development.

(3) The Chairman of the Armoured Fighting Vehicles Division (C.A.F.V.) is responsible for the provision of armoured fighting vehicles. Through the Director General of Armoured Fighting Vehicles he directs A.F.V. research and development.

## THE AIR FORCE

### *The Aeronautical Research Committee*

The first step taken towards a systematic study of the problems of aeronautics upon the basis of which alone efficient airplanes for national defence can be built, was the appointment of an Advisory Committee for Aeronautics by the Government in 1909. The late Lord Rayleigh, who had had a large share in the foundation of the National Physical Laboratory, was President of the new Committee, the late Sir Richard Glazebrook the Director of the N.P.L. its Executive Chairman, and among its members were Sir Horace Darwin, Mr. F. W. Lanchester, Mr. Mallock, Colonel O'Gorman of the Royal Aircraft Factory, and Professor (later Sir Joseph) Petavel of Manchester University. He succeeded Sir Richard Glazebrook as Director of the N.P.L.

The Committee had no executive powers but it advised on full-scale work at the Royal Aircraft Factory and soon afterwards an aerodynamics department was established at the N.P.L. Lord Rayleigh laid down the foundations on which the whole science of aeronautics has been built up and as a result the art of design developed rapidly in spite of the very primitive equipment, as it would now be thought, for model experiments at first available at Teddington. The work of the Committee was indeed most inspiring, largely due to the special engineering genius of Lanchester. The technical excellence of the aircraft of the Royal Flying Corps in World War I was largely owing to the work and guidance of the Committee.

After that war the report of a Committee under the chairmanship of Sir Richard Glazebrook to advise on future arrangements for aeronautical research and education led to the establishment of the Aeronautical Research Committee with wider functions and extended powers under the Air Ministry with Glazebrook as its chairman and the Directors of Scientific Research at the Ministry and the Admiralty, and later the Director of Research at the War Office with a representative of D.S.I.R. among its members. It remained advisory as regards the Ministry but

had in effect executive control of the work at the N.P.L. The researches carried out there had led to the development of accurate methods of investigating model planes and their parts and a fuller appreciation of the difficulties in applying model results to full-scale planes. Much work had been done on problems of stability and the study of new light alloys had yielded valuable results, while a great increase in the general knowledge of the flow of fluids over surfaces had been obtained.

Sir Richard Glazebrook retired from the chairmanship of the Aeronautical Research Committee after twenty-four years during which aeronautics had grown from its primitive beginnings into an important industry. It was mainly due to his vision, energy and ability that we had by that time 'an organisation second to none in the strength of its links from the laboratory to the finished product' (Report of the Committee for 1932–33). The men who have been engaged on applied research and on the experiments necessary to promote safety, reliability and efficiency have always been in close touch with the scientific members of the Committee and the designers in the industry have been linked up with the Royal Aircraft Establishment (the successor of the Royal Aircraft Factory) and directly with the Committee. This close and friendly collaboration of all elements is nowhere surpassed today. Sir Richard Glazebrook was succeeded in the chairmanship of the Aeronautical Research Committee by Sir Henry Tizard.

An outline of the work done in the Aerodynamics Division of the N.P.L. is given elsewhere (p. 278), but short reference must be made to other work which had engaged the attention of the Committee before World War II. As early as 1920-21 it was considering developments in internal combustion turbines and it started work on the dissipation of fog. In 1921–22, as the result of the Committee's advice, Mr. H. E. Ricardo was enabled to extend his researches on engines. In 1923–24 the Committee advised the use of aircraft to obtain daily records of pressure, temperature, etc. at great heights in aid of meteorological forecasts. In 1925–26 the Committee encouraged the supercharging of engines and of single-sleeve-valve engines; this last was justified by results obtained in 1931–32. During the next year the new compressed air tunnel at the R.A.E. proved of the greatest value as well as the vertical wind tunnel for the investigation of spinning. The Committee helped the investigation of Prof. R. V. Southwell into a method of calculating stresses in frameworks which has given important practical results. In 1933–34 the construction of a 24-ft. open-jet wind tunnel at the R.A.E. and the high-speed wind tunnel at the N.P.L. were completed. The researches of Ricardo into the air-cooled sleeve-valve engine led to the successful manufacture of such an engine by the Bristol Aircraft Co. widely used during World War II.

The great increase in speed and range of commercial aircraft has been due to the application of smooth surfaces and increased work on devices for safe landing, in all of which the Committee have had their part. It will be seen from this incomplete sketch how important has been the work of the Committee, not only for defence purposes but for the development of a civilian aircraft industry.

*Directorate*

Before 1924 there was a Directorate of Research at the Air Ministry but most of its work could not properly be so described, and in that year the duties of the office were divided and two Directors were appointed, one for Scientific Research and the other for Technical Development. The existing staff was divided between them and each Director was individually responsible for any work carried out on his instructions at the Ministry's experimental establishments. In the case of the aerodynamics division at the National Physical Laboratory the work was done on the advice of the Aeronautical Research Committee of which the Director of Scientific Research was a member. The programme of research to be undertaken at any of the experimental stations under the control of the Ministry was determined by the Director after considering proposals put before him by the Committee or by the stations themselves. On receiving the reports of the work done it fell to him to make his recommendations for further action, if any, to the member of the Air Council responsible for supply and research. The chief experimental stations which came under the Director for their research work were those at Farnborough, Felixstowe and Martlesham Heath.

How far the work done under the Director of Scientific Research should be treated as confidential to the Air Ministry is an easy matter in war time when the only other participants in the results are the other Defence Services which have increasingly co-operated in the researches undertaken. But in times of peace the problem is not so easy, for a similar embargo on the publication of the work done undoubtedly affects the scientific standard of candidates for appointment since the standing of a man in the scientific world largely depends upon his published work. From the beginning the policy of the Air Ministry has been less rigid than that of the other Defence Services, for they have been more willing to recognise that if this country is six months or a year ahead of others in any scientific discovery and its application it is usually as much as can be hoped for, while the purely scientific results can often be safely given to the world without delay. The problem has not been completely solved but the need for securing and retaining the ablest young investigators for the research departments concerned in defence makes its solution very important.

# PART IV

## INDEPENDENT INSTITUTIONS AFFECTING INDUSTRIAL PROGRESS

---

## CHAPTER 36

## NON-GOVERNMENT INSTITUTIONS

### UNIVERSITIES, UNIVERSITY COLLEGES, ETC.

There are eleven universities in England, one in Wales (with four constituent colleges apart from the theological college at Lampeter), four in Scotland and one in Northern Ireland. In addition there are at present three university colleges, unattached to any university, giving courses in preparation for a University of London degree. Two other colleges of somewhat lower status and degree of development have not yet received State aid through the University Grants Committee as all the others do.

These university institutions, all of which are independent of State control, are the most important sources from which the higher technical staff and above all the teachers for industry and the technological professions are recruited. Unlike the organisation of higher education on the continent where, almost without exception, institutions for higher technical education and research are independent of the universities, in this country and in the Dominions higher technological training is given in faculties of a university or in colleges forming part of the university itself. In the seventeen universities and three university colleges referred to above, no fewer than sixteen universities and two university colleges include engineering among their studies, while the corresponding figures for mining are nine universities and one university college. In addition to these two major subjects of study some universities make special provision for training in other industrial subjects.

The main schools are: *Aeronautics* (Cambridge, London (2 schools), Southampton University College). *Architecture and Town Planning* (Cambridge, Durham, Liverpool, London, Manchester, Sheffield, Glasgow (2 schools), Wales). *Brewing* (Birmingham, Manchester, Edinburgh (Heriot Watt College affiliated to the University) ). *Building Construction* (London, Manchester, Edinburgh (Heriot Watt College), Belfast).

*Colour Chemistry and Dyeing* (Leeds, Manchester, Glasgow). *Concrete Technology* (London). *Dairy Technology* (Reading, Glasgow (West of Scotland College of Agriculture), Wales). *Fuel Technology* (Leeds, London, Sheffield, University College Nottingham, Wales). *Glass Technology* (Sheffield). *Industrial Relations* (Cambridge, Leeds, Wales). *Leather* (Leeds). *Metallurgy* (Birmingham, Cambridge, Durham, Leeds, Liverpool, London, Manchester, Sheffield, Glasgow, Wales). *Naval Architecture* (Durham, Liverpool, Glasgow, Belfast (College of Technology) ). *Oil Technology* (Birmingham, London). *Technical Optics* (London). *Textiles* (Leeds, Manchester, Glasgow, Nottingham University College).

It will be seen that the university institutions of this country do much more than provide higher instruction in chemistry and physics, the essential bases of the scientific study of technology. They make material contributions through their professors and other higher staff to research bearing directly or indirectly on our manufacturing progress. The indirect assistance is to be found in the far-reaching and fundamental researches conducted at such places as the Cavendish Laboratory on atomic physics or the work done at Birmingham by Oliver Lodge on wireless or, going further back, that in London of Perkin on aniline dyes and Ramsay on the rare gases of the atmosphere. Many other instances will be called to mind.

The more direct assistance to industry can be exemplified by the work done on glass and leather technology at Sheffield and Leeds respectively. These two instances are important and for different reasons. When the Glass Research Association under the aegis of D.S.I.R. came to an end for reasons it is not necessary to describe, work of a scientific and technological nature was extended at Sheffield University, and the Department of Glass Technology there has become the co-operative centre to which glass manufacturers turn for help on their general problems (*see* p. 78). In the case of leather the first advances were made by W. R. Proctor when he became the head of the Department of Leather Industries at the Yorkshire College, later Leeds University. Since then the British Leather Manufacturers' Research Association has been formed, but the industry owes much to the early work at Leeds as well as elsewhere (*see* p. 85). It is of course debatable how far a university is wise in developing a very specialised aspect of technology as an integral part of its organisation, but the fact remains that the glass industry has found what it requires at a university when it failed to establish its own organisation.

## *Polytechnics*

In addition to the information given above with regard to technical subjects, in the University of London there are a certain number of

'recognised' teachers of that university in some of the London polytechnics. For example: *Civil Engineering* (2 schools). *Electrical Engineering* (3 schools). *Metallurgy* (1 school). There are also certain subjects outside the university curriculum which are of industrial importance, e.g. *Horology* at the Northampton Polytechnic Institute.

## THE ROYAL SOCIETY

In 1640 a group of Oxford and Cambridge men were in the habit of meeting from time to time to attend lectures at Gresham College which was founded at the end of the 16th century by bequest from Sir Thomas Gresham, and at which seven professors in turn gave daily lectures in their respective subjects. The bequest was vested in the Corporation of the City of London and the Mercers' Company. After some of these lectures these university men met in a professor's room at the college or at a tavern near by in order to discuss what was called the experimental or new philosophy based upon the views of Bacon, himself a Cambridge man. The meetings were suspended between 1658 and 1660, not because they were suspected by the Parliamentarians with whom most of the new philosophers, though not politicians, were in general sympathy, but because of the uncertain outlook in the final years of the 'trouble'. When the Restoration took place this group approached the King and found him sympathetic to the establishment of a Society or College, the members of which were to be described as Fellows, and in 1662 the first Charter of Incorporation was issued under the Great Seal to what was finally described as the Royal Society. In the following year a second and much enlarged Charter was granted extending, on the petition of the first Fellows, the powers of the new Society.

The purposes of the new body were very widely drawn and included both technical and practical inquiries as well as purely scientific investigations. This is clearly brought out in a draft preamble drawn by Sir Christopher Wren—one of the first Fellows and the professor of astronomy at Gresham College—which, though not actually used, gives a clear indication of what the founders had in mind. The preamble speaks of the promotion 'of useful arts and sciences' as the basis 'of civil communities and free governments' and of the collection of scientific information by 'laying in stock as it were of several arts and methods of industry'. In the second Charter of 1663 the purposes of the Society are defined as 'to improve . . . all social arts, manufactures, mechanicks' practises, etc.'

At an early date the Society appointed eight special committees to study various fields of inquiry that had come to their notice and among them one on the histories of trades and another on husbandry (the

Georgical Committee) which urged the Fellows to plant potatoes as a valuable food crop and to induce their friends to do the same. Industrial interests side by side with purely scientific inquiries were therefore an essential part of the Society's purposes. All the work was based upon carefully recorded inquiries and controlled experiments. This was a clear breaking away from the traditional deductive philosophy founded on a largely mistaken interpretation of the attitude of Aristotle. The King in 1662 made an effort to secure an endowment for this new undertaking by asking the Duke of Ormonde, then Lord-Lieutenant of Ireland, to make 'a liberal contribution from the adventurers and officers of Ireland for the better encouragement of them in their designes'. The President of the Society, Lord Brouncker, followed this recommendation by a letter to the Duke in January 1663 asking for a suitable grant of land, but neither action had effect. About the same time the King presented the Royal Society with a handsome mace for use at their meetings, but this was the sum total of their endowment apart from a grant by the King of Chelsea College which was in a serious state of disrepair. The College and grounds were later taken back by the King to make the Royal Hospital at Chelsea and a sum of £1,300 was given in exchange. Nothing was more foreign to the ideas of that time, or indeed of the present day, than that parliamentary funds should be granted to a scientific society for their general purposes.

In the absence of any official sources of income the Society attempted to secure the necessary support by admitting to their ranks many men of importance in the social and political fields, and from 1663–1830 more than two-thirds of the Fellows were non-scientific. It was hoped thus to strengthen the financial resources, but the results were meagre and it was not until 1830 and onwards when the Fellowship was increasingly confined to men of science that endowment gradually came their way from private sources. This was due no doubt to the consequent increase in their scientific output and to the growing general interest in scientific advance of which the foundation (1799) of the Royal Institution and later (1831) of the British Association for the Advancement of Science were indications.

By the end of the 19th century the financial position of the Society, in spite of its growing expenditure, was in a satisfactory condition. In 1940 the Society possessed a general purposes fund of £116,556 and no less than twenty-four special funds valued at £109,041 in 1939, including those for the award of medals and special lectures; in addition there were twenty-seven separate research funds for particular scientific investigations valued in the same year at £555,828. Moreover there is the Warren research fund for certain branches of physical science with a capital value of £173,400. The total funds of the Society in 1939, for



Plate XIX. Sir Humphry Davy, F.R.S.



Plate XX. Sir James Dewar, F.R.S.

specific and general purposes, amounted to about £875,600. One of the most interesting of the research funds is the Yarrow, out of the income from which the Royal Society establishes a number of research professorships. The holders are either existing members of the staff of the university to which the professorship is attached, or are additional to the existing provision. On the retirement or death of a Yarrow professor there is no undertaking or understanding that a Yarrow professorship will be continued at that university.

## THE ROYAL INSTITUTION

With the growing use of iron and machinery and the resulting great economic changes at the opening of the last century two new phenomena arose in the social life of this country, one intellectual and spiritual, the other an expression of it, the birth of a new class in the community. The first was the belief in the importance of individual opportunity, of 'self-help', the second was the emergence of a number of well paid, technically educated engineers, of whom the Stephenson family were the type. The first impressed Count Rumford and caused him to make 'the facilitating the general introduction of useful mechanical inventions and improvements' and 'the application of science to the common purposes of life' as the aim of the new Royal Institution. The second led to the establishment of a series of Mechanics' Institutes throughout the country, one at least of which developed later into a full-blown university institution, and in 1824 the Mechanics' Magazine sold 16,000 copies.

The Royal Institution is a 'foundation for the promotion of sciences and the diffusion and extension of useful knowledge'. Benjamin Thompson, Count Rumford of the Holy Roman Empire, its founder, was an American citizen of English descent and a soldier of fortune who had been sent to England in 1798 by the Elector of Bavaria as his Minister and representative. This last office he could not occupy for he had fought with the royalists in the American War of Independence and had subsequently been Under-Secretary for the Colonies. So George III claimed him as a British subject though he had held high office under the Elector.

This romantic figure was not only a distinguished man of science but a keen philanthropist. He decided to stay in England and in 1799 he launched 'a public institution for diffusing the knowledge and facilitating the general introduction of useful mechanical inventions and improvements and for teaching by courses of philosophical lectures and experiments the application of science to the common purposes of life', and so the Royal Institution of Great Britain was instituted. In spite of many vicissitudes and changes in its scope and governance, it has remained faithful to its original purpose and devoted itself under the guidance of

a series of remarkable men of science to the combination of outstanding researches in its laboratories with the exposition of their results in attractive public lectures. The most famous of these leaders was Michael Faraday, the son of a blacksmith, the young journeyman bookbinder, who largely by chance was appointed laboratory assistant in 1813 at the Institution. His amazing and epoch-making researches into magnetism and electricity were the foundation of the great electrical industry. He was also a distinguished chemist—he discovered benzene, the foundation of the colour industry, did work on glass for optical instruments and, as a metallurgist, produced new alloys of steel which later became of industrial importance.

But other distinguished men besides Faraday served the Royal Institution and contributed to the advancement of the practical arts. Before his time Sir Humphry Davy discovered sodium and potassium and invented the arc light, the first electric furnace and the wire gauze safety miner's lamp. John Tyndall succeeded Faraday as a resident Professor of Natural Philosophy at the Institution. Besides researches on the radiation and absorption of heat by gases which led to means of sterilisation, he did valuable work for Trinity House on fog-signalling. James Dewar, as Fullerian Professor of Chemistry, did pioneer work in the liquefaction of gases, developing Faraday's experiments on this subject, and determined the physical constants of liquid air, oxygen and nitrogen at the temperatures at which they exist. His work on the absorptive powers of charcoal had many practical applications, and led to its use in the manufacture of gas masks. His best known device is the vacuum flask.

Lord Rayleigh did some of his work on argon at the Institution, and later Sir J. J. Thomson and Lord Rutherford described their work on atomic physics at Friday Evening Discourses. Finally, Sir William Bragg became Fullerian Professor and resident Professor from 1923 till his death. He founded a school of research in X-ray crystallography which has many important applications and will certainly have more in the future.

The Davy Faraday Research Laboratory, presented to the Institution and endowed by the late Dr. Ludwig Mond is housed in an adjoining building. It accommodates about 20 workers in physics or chemistry approved by the Committee of Management. No fees are charged.

## ROYAL SOCIETY OF ARTS AND BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

There are two other scientific societies which, unlike those above referred to, appeal to a more general public and so bring the claims

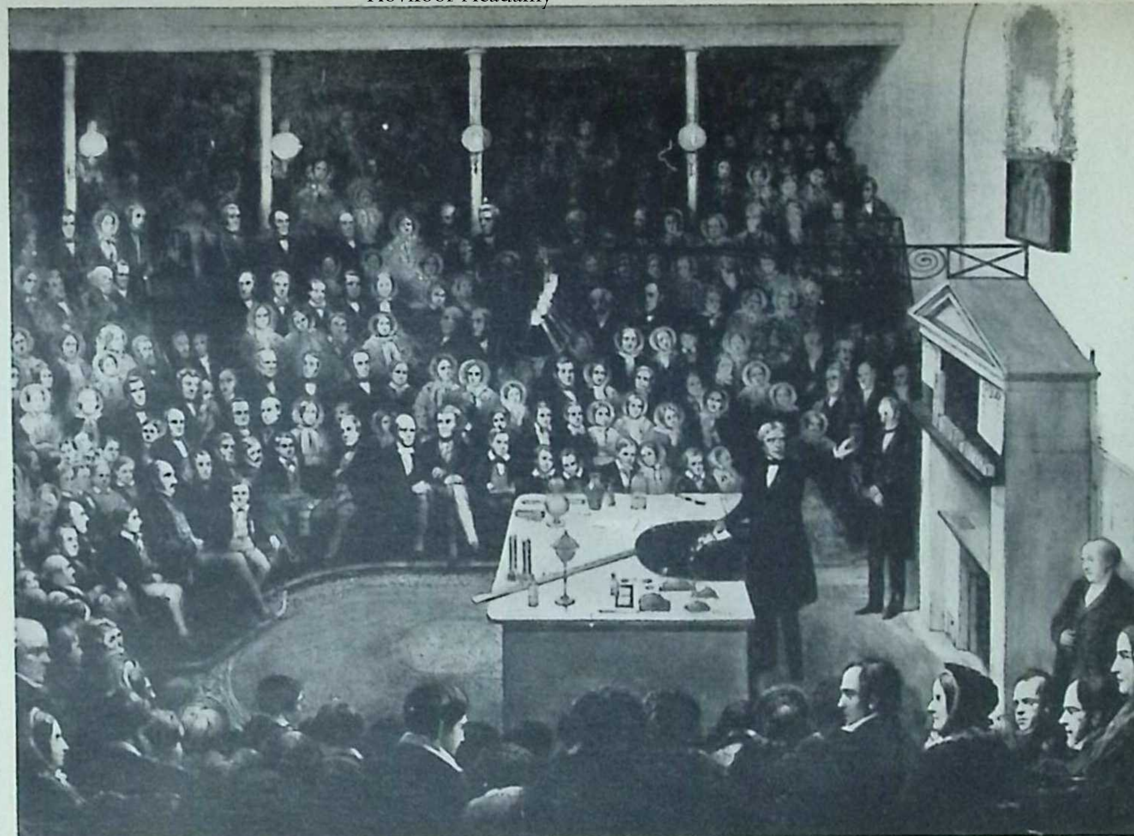


Plate XXI. Michael Faraday lecturing at Royal Institution in 1855 with the Prince Consort in the Chair, accompanied by the Prince of Wales (King Edward VII) and Prince Alfred (Duke of Edinburgh).



Plate XXII. Lord Rutherford lecturing on 'heavy water' at the Royal Institution in 1934.

and progress of science and its applications in industry to popular attention. The older foundation is the Royal Society of Arts which dates from 1754, long before the establishment of the specialist societies, and which deals with scientific, technical, industrial, commercial and artistic subjects, principally by lectures given by specialists. Since 1774 it has occupied the beautiful Adam building in the Adelphi and in 1847 it was incorporated by Royal Charter. Prince Albert was its president from 1843 till his death—another indication of the interest he was taking in the application of science and the arts in industry nearly ten years before the opening of the Great Exhibition. On 30th June, 1849, he called a meeting of the Society at Buckingham Palace and proposed that it should initiate the promotion of an exhibition of the work of all nations. The Society also fostered the establishment of the City and Guilds of London Institute and were the prime movers in the establishment of a national physical laboratory, for in 1842 they submitted a memorandum to the Government asking for the grant of the Kew Observatory as a laboratory and 'a repository for, and place for, occasional observation and comparison of the various instruments which the recent discoveries in physical science have suggested for improving our knowledge in meteorology, etc., in order that their relative advantages and defects may be ascertained'. Indeed when the National Physical Laboratory was founded some sixty years later it was at first located at the Kew Observatory, though the accommodation was soon found to be inadequate.

The other popular organisation for the encouragement of pure and applied science is the British Association for the Advancement of Science, founded in 1831, which holds annual meetings outside London (except in its centenary year) either in the provinces or in one of the Dominions. Although the scope of the Association is less wide than that of the Society of Arts, it is wider than the present range of the Royal Society for it includes education, though theories of education lie mainly in the field of applied psychology which is rapidly becoming an observational science. The various fields of work for each annual meeting are in charge of special committees of scientific leaders, each under a chairman of distinction. The committees arrange for the addresses to be given at the meetings of the several sections which last about a week, each address being followed by a discussion open to the public. In more recent years the Association has entered various fields of research in the care of specially appointed committees and financed out of the general and endowment funds of the Association. The majority of these deal with biological investigations but one deals with seismology and another with the preparation of mathematical tables. The total endowment for research at present is less than £500 a year.

## OTHER SCIENTIFIC AND PROFESSIONAL SOCIETIES

Nearly thirty additional scientific and technical societies were founded before the middle thirties of the present century for the encouragement of science by the holding of meetings and the reading of papers, but few of them have permanent officers and laboratories, like the Royal Institution, engaged in the conduct of original investigations. By the turn of the 19th century the interest in science and its applications had become so widely spread that the number of institutions founded in the next hundred years was no less than fifteen devoted to various sections of physical science, in addition to those devoted to biological and medical subjects. The earliest in date was the Institution of Civil (as distinguished from Military) Engineers (1818) designed to cover the whole of the mechanical arts as well as construction, but soon to lead to the establishment of distinct institutions for naval architects and for mechanical, electrical, marine, mining and gas engineers. Similar differentiation took place in the fields of chemistry and physics. In the present century the increasing specialisation in scientific studies and their growing application in industry has led to the founding of another dozen institutions ranging from the Institutions of Automobile Engineers (1906) and Structural Engineers (1908), to the Institutions of Production Engineers (1921) and Chemical Engineers (1922); from the Ceramic Society (1900) and the Institute of Foundrymen (1904) to the Institutes of Fuel (1927) and Welding (1935).

Several of the scientific societies have endowed, or administer funds devoted to, research or to professorships, fellowships, scholarships or other awards which have a direct bearing on industrial progress. Notes on some of these are given in Appendix V.

# CHAPTER 37

# THE CITY CORPORATION AND COMPANIES

The Corporation of the City of London has played its part in providing technical education. In 1866 a working classes industrial exhibition was held at Guildhall. Between 1881–1913 the Corporation spent £285,500 on technical education, and at various times since has given large sums to the University of London and other universities as well as to other educational work. Recently the Corporation made a grant of £10,000 a year for ten years to the University of London for its new building.

The City Companies, which were originally Guilds of Craftsmen and Merchants, have in course of time mostly abandoned their connexion with their original crafts or other purposes though some, for example the Fishmongers', the Goldsmiths' and the Gunmakers' have uninterruptedly maintained them. Some others have, however, adopted educational and research interests with a bearing on their original crafts and an outline of those related to scientific or technical education or to modern industrial research is given below. There are 81 Guilds in existence of which 12 are 'Great' Companies.

In 1878 a Conference of 23 Companies founded the City and Guilds of London Institute for the Advancement of Technical Education which was at first registered under the Companies Act in 1880 and in 1900 was incorporated by Royal Charter. Its activities fall broadly into three branches: (1) The City and Guilds College (the engineering section of the Imperial College) and the City and Guilds of London Institute; (2) The London Art School (in Kennington); (3) The Department of Technology (in Kensington) which, besides conducting examinations in technical subjects for students in this country and the overseas Empire engaged in, or preparing for, industrial occupations and issuing certificates on the results (*see* p. 325), acts as an unofficial co-ordinating body for technical education throughout the country. In the last sixty years the supporting Companies have given the Institute about £1,300,000.

Fifty-two of the Livery Companies contributed £124,753 towards the cost of a University Hall as part of the new buildings of the University of London and in addition the Goldsmiths' Company made a special donation referred to below. During the last fifty years practically all the Companies have shown an interest in promoting the craft or the trade with which they have been traditionally connected, but it is with their

activities in the field of productive industries other than agriculture that this book is concerned.

Some of the larger and richer Companies have made notable contributions in this field, e.g. *The Clothworkers* built and equipped the Department of Textiles and Colour Dyeing at the Yorkshire College, Leeds, now Leeds University, and have already expended some £430,000 there. An annual endowment of £10,000 is still given. To the City and Guilds of London Institute and the City and Guilds Engineering College at South Kensington their benefactions have exceeded £300,000 and before World War II their annual endowment was between £7,000 and £8,000. They have given £20,000 towards the Hall in the new buildings of the University of London. They have also assisted most of the technical schools dealing with textiles, e.g. Huddersfield, Halifax, Keighley, Dewsbury, Salt, Bingley, Batley, Ossett, Wakefield, University College, Bristol, Trowbridge, Westbury, Stroud and Polytechnics established in London. £17,500 has been contributed to the fund for building the Northern Polytechnic, Islington. They also, in common with many other Companies, give a number of scholarships and research grants annually.

*The Drapers* during the present century have made most important contributions to higher education and research in many universities and university institutions. Some of these grants fall outside the special scope of this book but they are of such significance for the general advancement of higher education that the following list includes benefactions to purposes other than industrial research because they have added to the strength of the centres in which technical education and industrial research is prosecuted and thus indirectly serve the studies with which this statement is directly concerned. The Drapers have spent nearly £500,000 on Queen Mary College, a 'school' of the University of London, though some of this was applied in earlier days to recreative purposes at the People's Palace. They contributed £30,000 to the incorporation of University College in the University of London, besides £300 a year for many years to the Department of Applied Statistics in that College. They have also given £5,000 to King's College, £2,000 to the School of Oriental and African Studies and £1,000 to Bedford College. At Oxford they provided buildings for the new Radcliffe Library, the electrical laboratories and the extension of the Ashmolean Museum. At Cambridge the aid they have given falls outside the scope of this book. At Sheffield University they provided the applied science Laboratories. At the University College of North Wales they built the library buildings and others for the University College of South Wales. Further, the Company have provided the physiological and hygiene laboratory at the Battersea Polytechnic and they have spent from £1,000

to £1,500 a year for nearly half a century on textile scholarships and exhibitions held in many provincial cities.

*The Fishmongers* maintain a Mark Quested Exhibition of £60 a year held alternately at Oxford or Cambridge for a graduate engaged in useful research, and have contributed £10,000 spread over seven years to the new central buildings of the University of London. They subscribe annually to the City and Guilds of London Institute, to the Marine Biological Association Laboratory at Plymouth, to the Freshwater Biological Association at Ambleside, Westmorland, to the Scottish Marine Laboratory and to University College, Hull.

*The Goldsmiths* have been the largest contributors to the City and Guilds of London Institute, their total contributions now exceeding £270,000. In addition, £87,000 was given for an extension of the City and Guilds College. The Foxwell Library of Economic Literature was purchased for the University of London and subsequently £50,000 subscribed for a building fund to house it in the new University building. A chair of metallurgy was endowed at Cambridge University and funds provided for the equipment of the laboratory there and for financing special research in matters affecting the gold and silver industries. Goldsmiths' College, New Cross, was founded as a technical institute and maintained by the Company from 1890 to 1904 when the site, buildings and equipment were presented to the University of London. Post-graduate research studentships were awarded at Oxford and Cambridge and the City and Guilds College continuously until the outbreak of World War II. A grant was made to King's College for Women (London), Household and Social Science Department. The Company have always been closely connected with the silversmiths' industry. Meetings of the trade associations, on technical and other subjects, are constantly held at Goldsmiths' Hall. They have under consideration a further scheme for research in post-war reconstruction.

*The Grocers*, besides making large contributions to the City and Guilds of London Institute, founded the well-known school at Oundle, which has an important engineering side. They have also endowed much scientific research.

*The Ironmongers* founded a fellowship of £500 and two research scholarships of £150 a year each at Sheffield University for cold working of steel and other ferrous metals.

*The Salters* founded in 1918 a Salters' Institute of Industrial Chemistry which awards fellowships, usually of £250–300 a year in chemistry and the allied sciences. Advice is given to young students as to courses of study. They also make grants to young persons of either sex in chemical works for further education.

*The Skinners* have done much to foster technical education through-

out the country. For some years they contributed £100 a year towards the salary of a lecturer in the Leather Industries Department at the Yorkshire College, Leeds. In 1898 they gave £5,000 towards the erection of special buildings for this department and £250 for ten years towards the salary of the teaching staff. In 1899 the new building was opened. In 1901 the Company gave a further £668 to meet the difference between the sum granted and the total expenditure. In 1878 they gave £3,000 towards the establishment of the City and Guilds of London Institute, and altogether have contributed over £120,800 including grants for prizes. They contributed £5,000 towards the new buildings of the University of London. They have aided the Leather Trades School at Bethnal Green and have given subscriptions to polytechnics, e.g. the People's Palace, Mile End, the Borough Road Polytechnic, and the Northampton Polytechnic Institute at Clerkenwell, to which they give £1,000 a year.

*The Vintners* since 1881 have annually supported the City and Guilds of London Institute. They grant annual scholarships of £250 to enable students to spend twelve months in the wine districts of the continent to study the art and production of wine.

The foregoing are among the so-called 'Great' Companies but the Companies referred to in Appendix VI are also important for their special activities in the promotion of technical education and industrial research. The information given above and in Appendix VI has been largely supplied by the Clerks to the Companies.

# PART V

# GENERAL FACTORS AFFECTING INDUSTRIAL PROGRESS

## CHAPTER 38

## PATENTS AND TAXATION

Legislative action has had a considerable bearing in two directions on the prosecution of research by industry and on the rate of progress made by the incorporation of new ideas into industrial practice. They are the patent laws and the mode of taxing industrial concerns. At first sight these two matters seem unrelated but in fact both are closely connected with industrial progress.

### *Patents*

It is not necessary to go into the question of the patent laws of this country in any detail; but grave criticisms of the present provisions have been made both from the point of view of the public and of the patentees themselves. The views expressed are conflicting and international issues are involved.

Recently (April 1944) an announcement was made by the Government that a Committee had been appointed with the following terms of reference:—

'To consider and report whether any, and if so what, changes are desirable in the Patents and Designs Acts, and in the practice of the Patent Office and the Courts in relation to matters arising therefrom.

In particular, the Committee is requested to give early consideration to, and to submit an interim report on—

(*a*) the initiation, conduct and determination of legal proceedings arising under or out of the Patents and Designs Acts including the constitution of the appropriate Tribunals; and

(*b*) the provisions of these Acts for the prevention of the abuse of monopoly rights;

and to suggest any amendments of the statutory provisions or of procedure thereunder which, in their opinion, would facilitate the expeditious settlement and the reduction of the cost of legal proceedings in Patent cases and would encourage the use of inventions and the progress of industry and trade'.

Criticism of the existing state of things takes four forms: (*a*) claims by the general public that powerful industrial corporations use patents to raise the price of their products unreasonably against the purchaser; (*b*) complaints by producers that progress by invention and discovery is prevented by other producers here and abroad taking out 'blocking' patents which they have no intention of working; (*c*) complaints by inventors and public alike that certain producers in order to prevent progress purchase new patents and inventions and put them in a drawer; and (*d*) that restrictive clauses are employed in the use of patents causing monopolistic positions. Criticism (*a*) is a fundamental objection to the granting of a monopoly for a period of time to a patentee or a manufacturer in any circumstances whatever and (*b*) an objection to a restraint of trade by the indeterminate extension of a monopoly by restrictive clauses added to licence rights.

Criticism (*a*). Unless a manufacturer can obtain some protection against competition for a reasonable time during the development and marketing of a new invention or discovery, he will not invest the necessary capital in new plant and advertisement. This consideration has increasing force as the amount of capital involved increases from the modern tendency of manufacture to grow in complexity and in cost. Direct proof of the influence of these conditions was provided some years ago by the inventor of the centrifugal cream separator. Conscious of the value of his invention of a small machine for domestic use he announced his willingness to grant free licences to manufacturers willing to make it. In the result it was never placed on the market.

Criticism (*b*). The question of 'blocking' patents is more difficult. There seems to be no doubt that the practice of the German dyestuffs industry* of taking such patents to hedge round an original master patent was a serious handicap to British firms before World War I though less was heard of this difficulty after geographical spheres of activity had been agreed between Imperial Chemical Industries Ltd. and the Interessen Gemeinschaft der Farbenindustrie. But where a new device rather than a chemical compound is in question it would be reasonable for the holders of a patent to cover the use of alternative means of producing the same result, though at the moment it may not be intended to use them.

Criticism (*c*). It has been suggested that if all patents were compulsorily endorsed with 'licences of right' this criticism would be obviated.

*It is known that before World War I the Badische Anilin und Soda Fabrik, a constituent member of the present Interessen Gemeinschaft, had a large staff of patent lawyers on their staff constantly employed in the study of German and foreign patents with a view to defending their company's rights and to devising so-called 'blocking' patents.

A patent so endorsed can be exploited by any firm or individual subject to the general conditions as to royalties, etc., demanded by the patentee. But if all patents were so endorsed the right of sole working, which is the essence of the monopoly granted by a patent, would be destroyed and the encouragement to the inventor thereby removed or diminished, thus tending to lessen the flow of invention or increasing their retention as secret processes, though secrecy is less possible in the case of mechanical devices. This tendency has been denied at least in respect of the manufacture of foods and medicine.

Criticism (*d*) is relevant in the case of international cartels. In some of these cartels there is a written agreement under which the parties agree that manufacture under a British patent shall be prevented or restricted in this country in favour of importation. British patents are intended to stimulate British manufactures and if a patented invention is not being worked in Britain, the patented article being made abroad, for instance in Germany, and imported into this country, the whole object of the grant of patents is defeated. In times of peace the localisation of the manufacture of certain products in Germany or any other foreign country may leave Great Britain without the plant, technical knowledge, and practical experience necessary for the manufacture of those products and without any operatives skilled in that manufacture. Meanwhile opportunities for the employment of capital and labour in this country are lost, and often an unduly high price for the products concerned is charged. Simultaneously corresponding benefits are ensured for the foreigner. In time of war this country is both deprived of supplies of the product and lacks knowledge, skill and plant necessary for its manufacture, deficiencies which can be made good only slowly and at great pains and cost. The enemy, on the other hand, can expand his output with relative ease.

The foregoing considerations deal only indirectly with the difficulties of the inventor. 'The true and first inventor' of a new idea which has been given patent protection is only at the initial stage of the journey towards a monetary reward. The gap between a laboratory result and commercial production is a big one and costly to bridge. Many troubles have to be surmounted requiring engineering experience and the construction of a pilot plant in which those troubles are revealed and cured. An inventor, as a rule, has not the funds to do this and unless his invention is a very convincing one, it is difficult to get a firm to embark on the necessary intermediate outlays. The story of Parsons' turbine is a classic example. It has been suggested that the Government might form a capital fund of considerable amount from which substantial grants might be made for undertaking these intermediate stages of promising inventions. A first charge on any subsequent royalties would be the

repayment of the grant, but unfruitful grants would be written off. Such a development fund might be held by the Imperial Trust under the aegis of D.S.I.R. which held the original Million Fund from which grants to Research Associations were initially made. The grants for the suggested purpose would have to be given on the advice of a strong and independent body of experts, including men with wide industrial experience. The same body might also advise the Comptroller of Patents in his present difficult duty of deciding whether and on what terms a patent should be endorsed 'licence of right' when an application is made to him to do so.

Meanwhile the Government has announced its intention after the war to allow lump sum payments for patent rights to be written off, during the life of the patent, and to allow the sum received as income of the seller to be spread over a number of years.

*Taxation*

It has been frequently urged that taxable profits should be real profits in the sense that those profits should be computed only after making all proper deductions and allowances, especially adequate allowances for the amortisation of money expended on assets which are used up in making profits. The Chancellor of the Exchequer in his Budget Speech of 1944 indicated that in the post-war period material changes would be made in computing the income tax of firms. It is not necessary to detail the arrangements to be made in future in regard to wear and tear of buildings and plant and to obsolescence. But the encouragement given to industrial firms to make greater efforts towards research and development is so important that it needs stating. There has been no greater encouragement given in this direction since the institution of the Million Fund for Research Associations. In the post-war period any research expenditure of a capital nature, which means expenditure on laboratory buildings, plant and machinery, pilot plant for development of laboratory work and the like, will be allowed over a period of five years or over the life of the assets, if shorter, as a deduction from taxable profits. In addition all current research expenditure such as salaries, wages, cost of materials and the like will be allowed as and when incurred. Moreover, any payment, whether for capital purposes or not, made to an approved Research Association will also be free of income tax, as will also any contributions made by a firm to research carried out by a university or college.

The advance in the application of science to industry and the consequent birth of new processes and inventions is becoming so rapid, and the need for industry to devote increasing attention to it so urgent, that the new concessions outlined by the Chancellor of the Exchequer are particularly timely.

# CHAPTER 39

# SCIENTIFIC PERSONNEL

Science yearly becomes more complicated and specialised as progress in knowledge is made, and the application of science to industrial processes and materials follows suit. Consequently the needs of industry demand increasing numbers of scientifically and technically trained people of various grades to man the relevant departments of firms and organisations. It has been estimated (Report of the London Chamber of Commerce 11th Jan. 1944) that the visible exports of this country need to be increased by £200,000,000 a year in order to pay for our imports. Other authorities put the necessary increase at a much higher figure. Taking the value of the cash exports in 1938 at £470,000,000 it has been calculated that, including a 50 per cent rise in prices compared with those at that date, the cash exports after World War II will need to be £1,100,000,000. To achieve such an expansion industrial production will have to be assisted by increased research and development, calling for much larger numbers of personnel of the right types.

In these days industrial improvements are the result of team work rather than individual endeavour, as was the case a century or more ago. Team work implies not only a well-knit and balanced set of workers for a particular quest or field of investigation but collaboration between workers in different fields of science. The engineer, for example, faced with some problem, may require a pure physicist or a metallurgist to help solve it. And when development work is undertaken, the constant association of the scientific laboratory with the production department is called for.

The various types of personnel necessary for successful industrial research and development need separate consideration.

## THE UNIVERSITIES

*Functions of a University*

Industry looks to the universities for two things. The continuous search after new knowledge of a fundamental nature, and the training of the higher grades of its scientific and technical personnel. The two are inter-related. For the performance of both functions the independence of the universities must be preserved, and they must not be trammelled by a central executive on the one hand or by the pressure of industry on the other as to the lines of investigation to be followed. Any

tendency to induce professors and lecturers to undertake for industrial concerns researches of importance to those organisations would result in a university department becoming in a measure a 'tied-house' instead of the place where wide fields of investigation were being explored. This must not be taken to imply that professors should not take consulting work. On the contrary, it is more than ever important that professors and other higher staff in the faculties of science and technology, and also those in faculties of economics, should obtain direct knowledge of the methods and problems of industry which their services as consultants can bring them. The greatest possible freedom must be reserved to the universities and their scientific departments so that they may lead, as they have so often in the past, in the breaking of new ground; in furnishing industry with fresh thoughts and ideas but not with solutions to specific problems.

Similarly in regard to personnel, industry looks to the universities to produce in sufficient numbers and of the requisite quality men and women well trained in the principles of the sciences they study rather than the details of the industrial applications of those sciences.

*Numbers of undergraduates*

Government has indicated that substantial increases in the State aid to the universities are to be made and the following table of approximate figures of comparison with certain other countries shows the position here to be unsatisfactory (*vide* 'Higher Technical Education' by Professor Hutton, City and Guilds of London Institute. Nov. 1943).

| | *Population Millions* | *Number of Universities and University Colleges* | *Number of Students* | *Income of Universities, etc.* |
|---|---|---|---|---|
| Great Britain | 47 | 60 | 50,000 | 6½ million |
| U.S.A. - | 133 | 1690 | 600,000* | 100 ,, |
| Russia - - | 194 | 716 | 657,000† | 90 ,, |
| Germany - | 78½ | 115 | 133,629 | 28½ ,, |

The foregoing are global figures covering all the faculties. The prewar numbers of students studying science or technical subjects at university institutions aided by the University Grants Committee were as follows: In 1939 there were 4,667 men and 1,726 women undergoing

* Undergraduates, total students 1,340,905.

† In addition 2,572 Technical Schools, with 751,000 non-university students.

full time instruction for a first degree or diploma in pure science. In technology, excluding medicine and agriculture, there were 4,819 men and 81 women similarly engaged; or an all-over total of 11,293 full time students in these two groups. It must be remembered, however, that many of the students in pure science are reading those subjects with a view to teaching them in schools, and that they include those studying the biological sciences.

The number of part time students is not so readily available. The total number of part time students including 'occasionals', but excluding postgraduates, studying all subjects (including the humanities) was 9,140 men and 2,262 women. Of these a considerable proportion were studying science or applied science.

*Undergraduate training and awards*

At the undergraduate stage there are many agencies by which promising boys and girls can proceed to university institutions for higher education and many forms of assistance are given in science subjects. It is only possible here to refer to the State and local education authority agencies operating to this end.

Since 1920 the Board (now Ministry) of Education have awarded State scholarships tenable by boys and girls at the universities and 360 of these are awarded annually. In some cases the tenure of these is extended to a fourth year. Nearly half the men recipients study science and mathematics but the majority of the women study the humanities. About one-third of the men and more than two-thirds of the women become teachers. The Ministry also award 20 Royal Scholarships, 11 Studentships in science tenable at the Imperial College, together with a few Whitworth Scholarships generally held at the same College.

After World War I the Ministry of Education launched a scheme for the further education and training of men whose education had been interrupted by the war, by making awards so that on demobilisation young men could proceed to university and technical institutions. Over 26,000 awards were made on that occasion. Any similar scheme to operate after World War II, and a scheme announced in Parliament in March 1943 has that end in view, will obviously entail a far greater number of awards. The figure of the previous war is likely to be doubled at least, having regard to the much wider categories, including women, employed in war service of one kind or another. An adequate supply of teachers, at all events of university calibre, will probably be the greatest difficulty the scheme will have to face.

In 1941 the Ministry of Education established a scheme of Engineering Cadetships. Whereas the Bursaries referred to below are designed to train boys and girls for technical work in the Forces or in responsible

civilian employment of national importance, the Cadetships are confined to boys for training for commissioned rank in technical units of the Services. The minimum initial qualifications for Cadetships are somewhat lower than those required from Bursars. The Cadetships are tenable at selected technical colleges nearest the boys' homes and usually extend over a period of 18–21 months. Here again, on demobilisation there will be a supply of technically trained men, running to several thousands, who were not available for industrial employment at the end of World War I.

A particularly important and interesting innovation has been made by the Ministry of Education for the purpose of creating trained personnel in radio and engineering and to a less extent in metallurgy and chemistry. A scheme of State Bursaries was published in 1941 for candidates normally still at school to enable them to proceed to universities for a maximum period of 2¼ years. From 1941–43, over 4,000 Bursaries were given in the two subjects of radio and engineering and these men and women with the additional technical experience gained in the Services will make available an additional corps of scientific personnel.

Local education authorities make senior awards of varying amounts to students attending universities, university colleges and technical colleges. In 1941–42 some 1,300 such awards were made to university institutions and some 200 to technical colleges.

*Numbers of postgraduates*

The figures of students engaged in 1939 on postgraduate study directly related to the manufacturing industries are shown in the following table:—

| | *Full Time* | | *Part Time* | |
|---|---|---|---|---|
| | *Men* | *Women* | *Men* | *Women* |
| *Chemistry* (including bio-chemistry and colloid science) - | 619 | 47 | 97 | 6 |
| *Physics* (including mathematics, geophysics and technical optics) - - - - - - | 281 | 24 | 114 | 11 |
| *Engineering* - - - - - | 239 | 2 | 121 | — |
| *Geology, Metallurgy, Mineralogy, and Mining* - - | 76 | 5 | 9 | 1 |
| *Technology* (fuel, oil, glass, leather, textiles and dyeing) - | 68 | 2 | 21 | 1 |
| Total | 1,283 | 80 | 362 | 19 |

This output of university-trained men and women will need to be greatly increased by enlarging existing institutions and departments and by adding to their number. The quickest way to secure the required output will be by strengthening existing institutions rather than by creating new ones. Institutions not yet of full university status might in course of time reach that standing and the creation of a university centre on the lines of the Imperial College of Science and Technology might perhaps be developed in the North of England and another in South Wales. The Royal Technical College, Glasgow, would provide for Scotland the nucleus of a centre of the kind.

*Postgraduate fellowships, etc.*

Assistance is given by many bodies to encourage research at institutions of higher education, particularly at the universities, in the form of fellowships, studentships and scholarships of various kinds. The brief particulars given below relate only to the sciences other than medicine and agriculture. Open awards are made by private and public bodies other than universities and colleges, e.g. the Royal Society, the Royal Commission for the Exhibition of 1851, the Royal Institution, the City Companies and others. The value of these awards ranges from £800 a year to £150, with very few below £250. Open awards are also made by universities and colleges and range in value from £150–£400, most of them of the value of £250 a year. Other awards, restricted to candidates from particular localities or institutions are also made. This information is taken from a useful pamphlet descriptive of these awards issued by the Royal Commission for the Exhibition of 1851. Further information is obtainable by reference to the Year Book of the Universities of the Empire for 1938. Besides these awards for research, there are the grants made by D.S.I.R. to selected postgraduate students for training in research and the Senior Research Awards, described on pp. 254–5.

Recently one of the most important groups of scientific firms in the country—Imperial Chemical Industries—has offered to provide at nine universities in Great Britain, fellowships for senior workers in certain sciences of an average value of £600 a year. The scheme will be administered by the universities themselves and they will determine the salary to be paid in each case. It is intended that the Fellows shall engage both in research and in teaching and that they shall be additional to the existing provision of the university departments in whatever way is thought best. The Fellows will be members of the university staffs and they will be concerned only with the duties assigned to them by the university. Twelve fellowships have been offered to each of the Universities of Oxford, Cambridge and London; eight each to Glasgow, Edinburgh, Manchester, Liverpool and Birmingham; four to the University of

Durham. The scheme is to run for seven years and the hope is expressed that the various universities will co-operate in working the scheme so as to avoid overlapping by any attempt 'to do something which is manifestly much better done elsewhere'. The subjects laid down are those that constitute the background of modern industry—physics, chemistry and the sciences dependent on them, as well as metallurgy and engineering. The proposal appears in effect to be the establishment of a new series of research readerships, by means of which leaders may be developed to undertake the strategical operations which are necessary to the successful tactical manoeuvres of industrial research.

An interesting scheme has recently been adopted by a number of employers to promote the postgraduate training of university students in the principles and technique of ferro-concrete design. A group of contractors in building and civil engineering have founded bursaries for graduates in engineering in connexion with the new professorship of concrete technology at the Imperial College. This in itself is an indication of probable openings for suitably qualified technicians.

A similar line of thought seems to have inspired the recent establishment by the Governors of the Bank of England of a trust fund of £100,000 for the promotion of economic and financial research—a plan falling outside the scope of the present book but closely related, in its effects, to industrial research.

*University courses and industrial needs*

While it is important to ensure that the freedom of the universities is maintained their policy should be framed with full knowledge in the relevant faculties of the needs of industry. More might well be done to make university staffs and their students better acquainted with the operations of industry. Steps in this direction have already been taken. The so-called 'sandwich' system is a feature in several engineering courses by which the university training is dovetailed with industrial experience, under university approval, in engineering works. Thus the student becomes familiar with works practice as part of his degree or diploma course, but neither engineers nor professors are unanimous as to the wisdom of this arrangement.

At the Massachusetts Institute of Technology a much more closely knit co-operation exists between the Institute and the works than has been attempted here and one at least of the disadvantages of the 'sandwich' system seems thus to be avoided. The significant difference in what is called the 'Co-operative Course' of the Institute's department of electrical engineering, for example, is the provision of alternating periods of fifteen weeks in the Institute and the works and the permanent stationing of a comparatively junior member of the faculty at each

firm to 'supervise the educational value of the work the students undertake'. This implies, of course, a limitation of the number of firms involved and of their distance from the Institute.

In a few universities here, students in science and technology undertake work in industrial concerns during vacation periods. They are thus able to see something of industrial life and its prospects. If some are deterred by the experience, that is all to the good, for it will show they have chosen wrongly while there is yet time to think again. At well-arranged works courses, students are given a general acquaintance with the firms' operations, by working for periods as employees, doing jobs as temporary members of the staffs. As a result, firms by these means can, and often do, enlist new recruits for their industry. Students are normally paid at the regulation rates. The plan is a good one and has worked well but it has to be remembered that the long vacation extends over but ten weeks and in a three-year course less than thirty weeks are thus available, for some holiday in summer is essential.

*Industrial plans for recruitment of staff*

A few of the leading firms with extensive research laboratories have adopted special plans for recruiting and training their scientific staffs and it may be instructive to describe briefly three such schemes. In one firm a number of promising graduates are selected from the faculties of pure and applied science in consultation with the professors and after interviews with the firm's senior scientific staff. These recruits with high academic qualifications are then trained for three years, including a period of general engineering experience in the factory. For the first two years the trainee is normally paid at the standard apprentice rate and in the last year a salary corresponding to that of a junior member of the permanent staff, though these emoluments may be varied in an upward direction in special cases. During his course of training, the young graduate is given opportunity for conducting a variety of investigations under the supervision of the senior members of the department. The trainee spends as a rule about three months in the different sections to which he is successively attached and has to compile reports on his work. The insistence on the writing of reports as part of the training is significant and the matter is one of wide importance for all postgraduate students. The trainee also attends lectures given by senior members of the department from time to time. The course of training is designed to show how the student's instruction gained at his university is linked with scientific industrial practice and how this in turn is closely associated with work in the factory.

No attempt is made to bind the trainee to remain with the firm and he can leave at any time, either during his training period or at its con-

clusion. Attendance at postgraduate lectures at the local university is encouraged, as well as membership of scientific and professional societies. In effect the scheme is analogous to that of the Department of Scientific and Industrial Research for the training of students in research referred to above, with this difference: whereas the Department's grants are mainly for training in academic research under a university professor with the double aim of creating schools of research and ensuring that the students are well trained in research methods, the firm's scheme is for training in industrial research.

Another plan is adopted by a leading firm, also in an industry based on science, for recruiting and training its junior research staff. No boys are enlisted unless they are sufficiently above the average to justify expectation of their obtaining a degree at London University as external students; every effort is made to prevent a dead-end occupation for boys. With the girls it is different. They are engaged for laboratory jobs requiring no professional qualifications; these are in fact dead-end jobs. But a very high percentage of the girls employed leave the firm in due course to be married.

The boys come to the firm in possession of an Intermediate B.Sc. qualification obtained at school, and generally are 18–19 years of age. They are engaged on condition that they attend evening classes and sit in due course for the final B.Sc. examination. Time-off is allowed in the late afternoon to attend such classes, with three weeks' leave before their final examination. Any spare time during working hours at the firm can also be devoted to study. Class and examination fees are paid by the firm, and the boys receive a weekly wage conditional on satisfactory reports on their progress at the classes and on their laboratory work. On taking their degree, they become junior members of the scientific staff of the laboratory. The same arrangements apply to girls provided they have obtained their Intermediate B.Sc. qualification at school. A considerable proportion of the scientific staff of the firm has been recruited by these means.

A third plan adopted by a large firm in a different industry of great importance has the following features for different types of employees. Apprentices of 15–16 are recruited from Junior Technical Schools and they must attend one day a week during the winter session at a Technical School. Those that obtain certificates in different subjects receive wage increases. After about four years the standard of the Ordinary National Certificate is reached and the apprentices proceed further with the help of Cadetships (see above). An opportunity is also given to promising young men on the staff to better themselves in the following way. An examination is held once a year for those below twenty-five years of age. On the results, four to six are selected and given a special training for two years by being passed through all the departments of

the works. If their promise justifies it, these selected employees are then sent, at the expense of the firm (fees and subsistence allowance are paid) to the university institution in the vicinity, where they often succeed in winning scholarships. The graduate staff is recruited from the same university institution as a rule and arrangements are made whereby the firm undertakes to appoint two to four graduates every year whatever be the state of trade, so that the institution may rely on this avenue for the employment of its graduates.

Plans of recruitment and training on the lines of those described are followed by other firms, though perhaps not so generously as a rule. Many Research Associations and Government laboratories employ similar methods to a certain extent.

*Scientific direction*

The need for larger scientific staffs in our industrial laboratories is not the whole story. There is also a growing need for more scientifically trained persons on the directorates of industrial manufacturing companies. At present it is rare to find men with a scientific training on boards of directors and still rarer to find among their number the head of the firm's research department, however important he may be to the operations of the undertaking. He may have high scientific qualifications, with an education greatly superior to many of the directors, but he is regarded only as a valued employee to be summoned as and when required to explain issues beyond the scientific comprehension of the directorate. He takes no responsible share in the policy of the firm. In Germany contrariwise it is common to find that a half or more of the directors of an industrial concern are scientific graduates.

In some cases where a distinguished man of science has been placed on a board of directors his usefulness in solving business problems has been so great that he has found it impossible to keep up his close connexion with scientific investigations. In no case of such appointments is there evidence that the innovation has had anything but good effects upon the firm's work. Only by a much greater extension of this leavening process can industry in this country become really scientific and research-minded. The days when high-sounding names and titles were a guarantee of soundness, or even of respectability, are past. And so should be the days when the son of a successful industrialist can expect a life of leisured affluence by succeeding to a seat on the board of his father's firm, however slight his intellectual qualifications for it may be. In too many cases firms founded and brought to success by a distinguished man of science have on his death or retirement ceased to be scientifically progressive and have relied for their prosperity on the guidance of finance. But such a set-up will sooner or later fail.

## TECHNICAL COLLEGES AND SCHOOLS

*Position prior to World War II*

In addition to what is done on the university plane provision is made by the Local Education Authorities of the country for technical education in colleges and schools maintained by them with grant aid from the Ministry of Education. Before World War II and under the provisions of the Education Act of 1921, Local Education Authorities (i.e. the Councils of Counties and County Boroughs) possessed wide powers, and wide discretion in their use. Technical colleges were established in most of the County Boroughs and in a large number of the larger County centres. The cost of their maintenance, after deducting income from fees and any other sources, was met in equal proportions from the rates and by grants from the Ministry. Loan charges for capital expenditure were met in similar fashion. The regulations governing the Ministry's grants were broadly drawn and the conditions attached to them gave free scope for the institution of courses of instruction of all kinds.

In comparatively few cases technical colleges were not provided, but aided, by the L.E.As. In this class are included the London Polytechnics, at many of which very advanced work is undertaken and at certain other colleges outside London where Municipal Technical Colleges were not established. For instance, at Sheffield the higher technical education is conducted at the University with aid from the L.E.A.; at Southampton the University College there makes the provision with aid from the County Borough and County Authorities (L.E.As.); while at Bristol and Nottingham the Merchant Venturers' College and the University College respectively receive direct grants from the Ministry and not from the L.E.A. for work which falls within the scope of its regulations.

The foregoing brief outline indicates the general layout for the provision made in the country prior to World War II. In the McNair report on Teachers and Youth Leaders of May 1944 (*see* p. 330), it is stated that in 1938 there were in England and Wales a million and a quarter students pursuing part-time education predominantly vocational in character, of whom 41,500 were released from industry for attendance at classes during the day. In addition there were 43,000 full-time students at technical and commercial colleges or schools. It must be remembered, however, that these are global figures and include craft students of all kinds, students attending perhaps only for single subjects for special purposes, students attending commercial, domestic, and women's trades classes: in fact a whole range of subjects which are not pertinent to the subject of this book.

*National Certificates and Diplomas*

Large numbers of these students attend the classes to obtain National Certificates and National Diplomas. In 1921 the Ministry of Education in collaboration with certain professional bodies arranged a scheme whereby National Certificates were awarded by the Ministry in conjunction with the professional institutions to students who followed progressive part-time courses under approved conditions. The Certificates are of two grades—the Ordinary National Certificate and the Higher National Certificate. The former is awarded after attendance at part-time courses (usually of three years' duration), and success in the final examination, to students of about 16 years with an adequate previous education on entry to the courses. The Higher Certificates is given as a result of attendance (and successful examination) at advanced part-time courses, usually of two years' duration. It is designed for students who have obtained the Ordinary Certificate or who have reached a similar standard of attainment.

The scheme was started in 1921 and the following table indicates its growth in the range of subjects dealt with and the professional bodies co-operating with the Ministry. The table also shows the numbers of Certificates in the two classes awarded in 1939.

The number of candidates presenting themselves for examination for Ordinary Certificates in 1939 were 3,441 and 2,058 for mechanical and electrical engineering respectively, 822 for building, 326 for chemistry, 155 for textiles and 40 for naval architecture. For Higher Certificates the numbers were 850 and 675 for mechanical and electrical engineering respectively, 192 for building, 88 for chemistry and 86 for textiles.

| *Subject (year of institution given in brackets)* | *Professional body associated with the Ministry* | *Ordinary Certificates 1939* | *Higher Certificates 1939* |
|---|---|---|---|
| Mechanical Engineering (1921) | Institution of Mechanical Engineers | 1833 | 632 |
| Chemistry (1921) | Royal Institute of Chemistry | 196 | 58 |
| Electrical Engineering (1923) | Institution of Electrical Engineers | 1133 | 421 |
| Naval Architecture (1926) | Institution of Naval Architects and Worshipful Company of Shipwrights | 19 | — |
| Building (1929) | Institute of Builders | 533 | 145 |
| Textiles (1934) | Textile Institute | 111 | 75 |
| Production Engineering (1941) | Institution of Mechanical Engineers and Institution of Production Engineers | — | — |
| Civil Engineering (1943) | Institution of Civil Engineers | — | — |

The courses are designed to give training in the fundamental scientific principles underlying the industries concerned and a minimum number of hours is prescribed, but almost invariably exceeded. The courses normally involve attendance at evening classes thrice weekly through the winter. At some colleges and schools the classes are held in the daytime by arrangement with the students' employers. In production engineering and civil engineering only Higher Certificates are awarded.

The National Diplomas, Ordinary and Higher, are confined to the three subjects of mechanical engineering, electrical engineering and building. The Ordinary Diploma is awarded to a successful candidate usually at about the age of 18 after pursuing a full-time course for a minimum period of two years. The Higher Diploma is awarded after a successful course of advanced full-time instruction, extending as a rule over three years and sometimes four.

In 1939 there were 73 candidates for Ordinary Diplomas in each of the subjects of mechanical and electrical engineering, and of these 62 and 48 respectively were successful. In building there were 22 candidates and 16 passed. For the Higher Diploma 31 candidates out of 35 were successful in mechanical and 8 out of 12 in electrical engineering. In building 8 out of 9 candidates were successful.

This scheme of National Certificates and Diplomas, amplified and extended, as it will doubtless be, as the new Act is put into operation, provides an important element in the provision of technicians for industry but it does not necessarily exhaust the possibilities. To make suggestions for the extension of these facilities, a strong committee under the chairmanship of Lord Eustace Percy has been appointed to consider the relations of universities and technical colleges in the field of higher technical education, having regard to the needs of industry. The findings of the committee will appear in due course, but it would seem that much is to be said for the institution of higher grade colleges at centres of industrial activity peculiar to an area, either as departments of a national character attached to existing technical colleges or as separate institutions. The idea of the possible formation of still higher grade institutions on the lines of the Imperial College of Science and Technology in the north of England and possibly in South Wales has been suggested elsewhere (p. 319).

### *Laboratory operatives*

Equally important is the provision of an adequate number of trained laboratory operatives, skilled mechanics, draftsmen, glass-blowers and the like. This country has been denuded of such essential men, partly owing to the entirely inadequate recompense they received for their services. In the inter-war period it was not uncommon to find skilled

mechanics receiving a wage less than that of a bus conductor, and in times of acute industrial depression highly experienced foremen accepting employment as ordinary mechanics. No wonder that this country lost the services of important personnel to other countries or that sons were deterred from following in the footsteps of their fathers. An adequate supply of first-class skilled operatives is an essential for British industry.

*City and Guilds Certificates*

Among the large number of persons undergoing instruction in technical and vocational subjects quoted in the McNair report, many seek qualifications through the City and Guilds Certificates. The Guilds of London play their part and the Institute's certificates are a criterion of the skill of those who obtain them. But, they are not the only yardstick by which to measure the output of skilled craftsmen. The number of candidates who sat for examinations conducted at 556 centres in Great Britain, Northern Ireland and Eire in 125 subjects in 1939, was 34,173 and, of these, 22,000 passed. Some of the chief groups of subjects were:

| | | |
|---|---|---|
| Telecommunications - - | 15,659 | candidates |
| Automobile engineering - - | 1,174 | ,, |
| Textiles - - - - - - - | 1,861 | ,, |
| Building trades - - - | 2,712 | ,, |
| Carpentry and Joinery - - | 1,082 | ,, |
| Metallurgy, including welding - | 1,136 | ,, |
| Gas fitting - - - - - | 2,139 | ,, |
| Machinists', Turners' and Fitters' | 770 | ,, |

There are, however, large numbers of operatives and highly skilled men who become available without this particular credential. The position is therefore not so serious as the figures would imply.

*Building requirements*

It became increasingly evident to the Ministry of Education in the inter-war period that the buildings and equipment of many of the technical colleges fell short of modern standards, and while several had been reconditioned and well equipped buildings erected, recurrent periods of depression and restrictions on public expenditure handicapped progress. Consequently in 1936 the Ministry drew up a comprehensive building programme involving an estimated expenditure of £12,000,000 to provide technical education throughout the country with up-to-date facilities. Some progress was being made with this scheme when World War II put a stop to it.

*Education Act of 1944*

Such then in broad outline was the provision in the country for technical work and its output before the Education Act of 1944. Substantial changes are made possible under this Act. Leaving aside the great alterations prescribed for elementary and secondary education—important though they are as bearing on the preparation of boys and girls for further technical education—the outstanding factor in regard to this grade of education is the conversion of a permissive power into a duty. The Minister of Education can direct L.E.As. to prepare and submit schemes of further education for approval. The Act of 1921 provided for the preparation of such schemes but there was no effective power to see that a scheme on paper was put into operation. Under the new Act the L.E.A. has the duty 'to take such measures the Minister may from time to time, after consultation with the Authority, direct for the purpose of giving effect to the Scheme'.

To avoid wasteful overlapping a L.E.A. must consult the Authorities and other bodies for adjacent areas in preparing a scheme, and this will ensure a broad treatment of technical problems not limited to the areas of individual Authorities.

The estimated additional expenditure by the State on technical and adult education consequent on this new legislation is put at an ultimate figure of rather more than £8½ millions a year, which includes allowances for loan charges on capital outlays for technical college buildings and equipment involving more than double the pre-war estimate of £12,000,000. Another factor in the new legislation which will have an indirect effect on the quality of technically trained personnel is the proposed institution of County Colleges for those of age range 15–18. Many of the young people trained there will be better equipped to go forward to higher technological studies.

*Industrial experiments*

An interesting training experiment calls for some description since something on the same lines might be considered in other directions. During the inter-war period there was a rapid development of the iron founding industry and a shortage of adequately trained technical and executive officers in an industry previously conducted mainly on a craft basis. In 1935, the British Cast Iron Research Association established a staff college for the industry, known as the British Foundry School. This school, unique in character, operated until the outbreak of World War II when its operations were suspended. The industry has already expressed a desire for its re-establishment. The school was aided by the Ministry of Education and accommodated by the Birmingham Education Authority, under a joint advisory body. The governing body was

drawn from the industry and the Research Associations concerned. The school was national in status and awarded a diploma, endorsed by the Ministry of Education. It provided an intensive full-time course of one academic year, the curriculum covering foundry organisation and planning, the raw materials, processes and equipment of the industry, together with the principles of the sciences involved. Students were admitted on the nomination of their employers as men who had shown promise of leadership and likely to be fit for higher responsibilities. No practical training was provided, as students were required to have adequate practical experience, combined with suitable technical training, approximately equivalent to Higher National Certificate standard. Visits were paid to foundries each week, and after the diploma examination, a visit was also paid to a group of foundries, either at home or abroad. The students continued to receive their salaries and had their fees paid. A small permanent staff gave the basic instruction and in addition a group of specialised lecturers actually engaged in the industry provided about 120 lectures during the course, which covered both ironfounding, steelfounding, and non-ferrous founding, and was designed to enable students to plan and adapt a foundry for any purpose or output.

The school did not duplicate any other institution and sprang from a knowledge of the requirements of this country after a close study of the leading features of institutions serving a similar purpose in Europe and America. The very close contact of the school with the industry and the knowledge possessed by the students of what they wanted to learn were major features in its layout. Its success turned on the co-operation of employers in sending promising men to the school, and the somewhat limited advantage that was taken of its facilities during the inter-war years may be explained by the difficulties of the period and in particular the reluctance of employers at that time to release their personnel for the additional training. With a development of technical training through the country, the ironfounding industry should make greater use of the school and other industries may profit by a study of the experiment.

It is certain that, after the war, firms in all industries will have to pay more attention than they have hitherto to the training of operational personnel. In the old days the system of apprenticeship supplied the need, but in modern conditions, where the journeyman is working under piecework systems, he cannot be expected to sacrifice his earnings in training apprentices. The attraction of the Defence Services and the plans adopted for recruitment through the Cadetships given by the Ministry of Education (p. 317) have meant that the individual firm has had a very poor chance in competing for the services of young men. The

suggestion has been made that engineering and shipbuilding firms should start their own trade school and undertake to employ all the trained apprentices it produces, while part of the cost would be provided by suitable work undertaken by the school and paid for at accepted market rates. That appears to be a sound and promising plan which it is hoped will be realised after the war.

Another scheme of interest is the following: A large firm near Sheffield has established a college for apprentices which includes a number of training centres preparing young people for service in commerce, engineering, mining, welding and foundry practice. The young recruit is first interviewed when all details of family, medical and school history are ascertained and intelligence tests applied. After a first month during which close observation is kept on behaviour, progress and success under special tests, the parents are advised as to the type of work best suited to the applicant. A general or vocational course is then taken. Pay is given at the rate of the selected department and all training equipment and apparatus are provided by the company. The nature of the work in each branch of the company's business is explained in the pre-entry course. In that for mining, for instance, the diversity of jobs open to mining apprentices is illustrated by photographs and the line of promotion through any one of them explained. Every effort is made throughout to interest the apprentices in the business as a whole, and emphasis is laid on the part played in human endeavour by the products of their labour.

## TEACHERS

### *The McNair report*

'Technical education in this country has never received the attention it deserves and there has hitherto been no systematic provision for the recruitment or training of technical teachers.' These are the opening words of the section of the McNair report (Teachers and Youth Leaders) dealing with technical colleges and schools; and they are a serious indictment. The report points out that under the Education Act of 1944 the establishment of compulsory part-time education with its vocational studies, and the provision of junior technical and commercial schools as a normal part of secondary education, will change the pattern of technical education and a much larger number of teachers of technical subjects will be required. In 1938 the number of full-time teachers in technical and commercial colleges and schools was about 4,000 and the report estimates that more than double this number of full-time teachers will be required to give effect to the provisions of the new Act, and that the annual replenishment rate cannot be safely put lower than 400-500.

Not only is the present supply of teachers entirely inadequate to deal with the requirements of the Act but the quality of the existing teachers is not as good as it ought to be. Industrial representatives stated in their evidence to the Committee that the teachers had insufficient knowledge of industry and were thus unable to adapt their knowledge and methods to the needs of the students. Many graduates with degrees in textile technology were not well grounded in the fundamental sciences associated with their work, while on the engineering side the complaint was added that touch with industry had been lost and that the instruction given was in consequence out-of-date.

*Use of professional institutions*

The report suggests that the professional institutions should be invited to co-operate by bringing into being standing committees charged with the duty of keeping constantly under review, and making practical proposals about, the co-operation of industry and commerce with technical education; and by facilitating arrangements for the periodic return of technical teachers to industry and commerce. The professional institutions cover all the main fields of industry and their membership includes the leading scientific and technical employees of the firms. In so far as their nominees are familiar with the educational standards required and with industrial needs, they will command respectful attention.

*Other agencies of importance*

Other agencies which might well be used to the same end are the Research Associations and the Stations of D.S.I.R. They have already played some part, though a slight one. The report makes but little reference to this possibility and some further study seems called for. All the Research Associations possess, through their instruments of government, powers to encourage and improve the education of persons who are engaged, or are likely to be engaged, in the industries they serve. But the small financial resources at their command have prevented many Associations from using these powers.

The textile Research Associations, especially those for cotton and wool, have done a good deal in helping to improve syllabuses and curricula by basing them on up-to-date textile knowledge. The British Cast Iron Research Association has been instrumental in establishing a Foundry School, referred to above. The British Launderers' Research Association (see also p. 246), in collaboration with the Institute of British Launderers has arranged for classes of instruction to be held periodically at its laboratories. These are only instances, and other Associations have acted similarly or are contemplating doing so. The

Stations of D.S.I.R. have also taken like action, notably the Building Research Station. Here refresher courses for architects were organised in 1933 and, when summer courses in building science were established by the Ministry of Education, part of the instruction was given at the Station. Extension of the facilities available at the Stations of the Department might well be used to further the end in view.

Short courses for engineering teachers have been conducted by the Ministry in association with industry, notably in mechanical and electrical engineering and in radio.

# CHAPTER 40
# STANDARDISATION

## *Definitions*

Standardisation is a long word for a process which has been in existence for hundreds of years. Without standardisation of our coinage there could be no public reliance on our currency, hence the milled edges of our gold and silver coins and the elaborate precautions against fraudulent imitation of our notes. Without standardisation of our weights and measures, daily commerce would be impossible. And as our manufacturing grows more complex an assurance that its products comply with the measurements necessary for their successful performance and that their quality will stand up to the strains imposed on them by use, becomes increasingly necessary. Electric lamp plugs must 'fit' and switches must wear well and avoid short circuiting of the current. There are hundreds of similar necessities in modern industry. Yet many intelligent people fear that standardisation means a freezing of progress and see in it a growing menace to personal initiative and individuality, which will lead to a dead uniformity that refuses all progress.

What then is the accurate definition of standardisation? In the first place, it is of two kinds: functional and dimensional. Functional standardisation includes all standards dealing with 'fitness for purpose'. They may deal with any of the following: *Terms and definitions*—to secure accuracy of description and to prevent confused thinking. Terms and symbols are the alphabet of industry; obviously they must be in standard form, like any other language, if the possibility of misunderstanding is to be eliminated. *Quality*—to measure fitness for purpose. Standards under this heading are based on composition or performance. *Methods of test*—to establish uniformity in methods of measurement and test, which will diminish the chances of dispute and facilitate comparison of results. Such standards encourage a more general adoption of testing by industry. *Methods of use* (*codes of practice*)—to define the correct application of materials and appliances. These standards cover the methods of installation and are designed to secure adequacy of result and diminish the chances of accident.

## *Objects*

Dimensional standards are established to achieve (*a*) simplification, (*b*) unification and (*c*) interchangeability. If an unnecessary multiplication of articles and appliances can be avoided the processes of manu-

facture and the replacement of parts will be simplified. Above all the stocks to be held by manufacturers and retailers will be reduced. Mr. Howard Coonley of the combined Production and Resources Board in the U.S.A. has remarked that 'To the consumer, simplification and standardisation mean better values, better service, quicker delivery, easier repairs and, above all, higher quality of goods for the same price. Vendors, wholesale and retail, can look to the expanding simplification programme to give them increased turnover, staple lines which are easy to buy and sell and greater concentration of sales effort on fewer items. They will have to invest less money in new stocks and repair parts, they will be able to get along more serviceably with smaller inventories. In general they will find in simplification and standardisation a universal engineer who will decrease their overhead and handling charges on all kinds of merchandise. In simplification and standardisation, the manufacturer finds the advantages of longer factory runs with fewer change-overs, fewer idle man hours, simplified inspection requirements, longer production units, less special machinery, less obsolescence in material and equipment and less chance of error in shipment and delivery.'

Dimensional standardisation may also be used as an indirect method of specifying quality.

*British Standards Institution*

But what of the tendency of standardisation to freeze progress? If true it would be a fatal objection. In the first place it does not imply an arbitrary control by some governing authority to frustrate the growth of new ideas. To be really effective it must rest on general consent and, with the advance of technical knowledge, standards must be reviewed from time to time and kept up to date. These two needs are secured by the machinery of the British Standards Institution which is in general charge of the methods of standardisation in this country. No British Standard is ever prepared unless a request has come either from the industry concerned or from a Government department interested in the subject. Standardisation works for the benefit of all and provides a basis for equitable transactions as between seller and buyer, or between producer and user.

The British Standards Institution has gradually developed out of an Engineering Standards Committee appointed by the professional engineering institutions in 1901. Since then its scope has been gradually widened until it now includes the preparation of standards for almost all important British industries. It received a Royal Charter in 1929 and has throughout had Government encouragement and support. It is a voluntary co-operative organisation developed by British industry, which has been officially recognised as 'the sole organisation for the

issue, in consultation with any Government professional or industrial bodies concerned, of standards having a national application'. Certain research bodies, among them some Research Associations, have issued standards of their own for industries in which they are concerned and it is to be hoped that arrangements may be made to co-ordinate their work in this direction with that of the British Standards Institution. This will be the more important since all the Dominions have established standardising authorities on the same lines as the British Institution, though they are more closely connected with their governments than is the case with us. In Canada and New Zealand the terms 'Canada Standard' and 'New Zealand Standard' have legislative sanction, and in South Africa the Union Government has power to restrict the use of standardisation marks to two South African marks and three British Standards Institution marks by the South African Standards Institution and by such manufacturers or other persons and institutions as have been authorised by the South African Institution to use them. By agreement with the British Standards Institution a licence issued to our manufacturers to use one or more of the British marks will be accepted as compliance with the South African requirements. Indeed the British Standards Institution is in continuous and close co-operation with all the Dominion standardising authorities with a view to implementing the resolution of the Imperial Economic Conference of 1931 which runs as follows: 'The Conference recommends that each standardising body should adopt a mark or brand to be applied under the licence or control of such body to goods which comply with standard specifications issued by it and are produced or manufactured within the territory which it covers and should take the necessary steps to secure for such mark or brand the full protection of law throughout the British Commonwealth of Nations whether by its registration, whenever possible, as a standardisation Trade Mark or in some other appropriate way.'

As yet, however, the British Standard Marks have not received the same legislative protection as have the marks in most of the British Dominions.

### *Advantages of standardisation*

Two important results have flowed from the growth of standardisation in this country which have intimately affected the progress of British industry besides its advantages to the manufacturer, the distributor and the consumer already described. In the first place, in order to determine the accurate measurements necessary for dimensional standards and the right ascertainment of quality or fitness for purpose needed for functional standards, much previous research has been called for and this research has had a direct and vital effect on the progress and effi-

ciency of all those firms that adopt British standards for their products. A recent extension of research into the statistical field is making the effective and economical control of modern large scale production far easier and quicker by revealing the existence of failures in machines or tools at an early stage and thus reducing the amount of testing of the finished product. This technique is known as the Statistical Control of Quality, or shortly as 'Quality Control' and it is so important a means of improving the efficiency of production that a short and non-technical account of it is given in Appendix VII by Sir Frank Gill. A special committee of the British Standards Institution is studying this question which is destined to play an increasingly important role in British industry.

A second important result which will flow, especially after the war, from the growth of standardisation throughout the Commonwealth and of co-operation in this field with the U.S.A. (through the American Standards Association) and with the countries of South America, especially the Argentine, is the effect it will have on our export market, the coming importance of which has been stressed again and again. British manufacturers will neglect the advantages of standardisation at their peril.

But improved speed and efficiency of manufacturing methods and effective simplification and new standards of quality will not alone bring new overseas trade or recover that lost during the war, especially in consumer goods. To these advantages must be added an attractive appearance—attractive that is in the eyes of purchasers with different tastes and different surroundings. In other words, to designs aimed at simplifying manufacture and making the articles more durable must be added artistic designs varied to suit the tastes of different overseas markets. This subject is dealt with in the following chapter.

# CHAPTER 41
# INDUSTRIAL DESIGN

*Importance to export trade*

No excuse is required for a discussion on industrial design in a book about industrial research. It is a subject to which far too little attention has been paid in this country and it bears closely on research on the scientific side. The matter received an entirely new degree of importance during the world-wide industrial depression of the early 1930's; and in the United States of America, considerable emphasis was given to it at that time. In this country also it received increased attention in the inter-war years. It is not possible here to give more than an outline of the main issues involved and the considerations to be borne in mind. *The Missing Technician in Industrial Production* by John Gloag, 1944, gives a thoughtful and stimulating review of the subject; and lectures on design at meetings of the Design and Industries Association by H. Strauss, M.P., Francis Meynell, T. Harrison, Herbert Read and James Bostock are also of great importance.

Industrial depression is not an unmixed evil. It provides a stimulus of a kind lacking in times of prosperity. A flagging market is a frightened market and fear is a goad sharper than either competition or price-cutting. The depression of the early 1930's was probably the most widespread in history. In this country, prosperous firms were operating at a loss and were seeking new means to increase their turnover. Scrap material previously thrown away was put to use and more economical methods of production were devised. Many of the innovations then instituted have persisted into better times.

But it was the conversion of the world market at that date from a seller's into a buyer's market that brought into prominence the need for better designs and for 'eye appeal' as the Americans call it. Articles never before designed for appearance, such as stoves, electric irons, refrigerators, vacuum cleaners, weighing machines, typewriters were then 'styled' to express efficiency, cleanliness, cheerfulness and unencumbered performance. Manufactures, previously designed solely for effectiveness, such as cheap clocks, fountain pens and motor-cars, were 'styled' afresh. A revolution occurred and a new profession was created —that of the industrial designer. Great pains were taken and high prices for first-rate designs were paid. Consumer-research—the technique of finding out what the intelligent buyer likes and wants—was

developed. It may be that in the years following World War II the markets of the world will again become those of the seller, for commodities will be scarce and in great demand to repair the ravages of war and the period of replacement may be prolonged. It is to be hoped that the lessons barely learned by 1939 will not be forgotten and will not be ignored in a get-rich-quick outlook. Especially is this important to a country striving to establish a permanently increased export trade in competition with industrial countries which have not suffered the restriction of consumer goods that we have.

### *Fields of design*

There are three distinct fields of industrial design: (1) design for the improvement of function, i.e. design to fit the article better to its purpose; (2) design to simplify production of the article; and (3) design to make the article more attractive in appearance.

Field (1). A good example is the streamlining of the aeroplane and the elimination of parasitic drag which has produced a body in flight on the lines of a fast-swimming fish. A classic example is the design of harness for draft-horses. It was not till the end of the 8th century, in the time of Charlemagne, that the harness of draft-horses in the West was redesigned so that no pressure was caused on the windpipe and the pressure taken on the shoulders of the animal. The horses were thus enabled to exert their full power over much longer stretches and the transport of heavy material was made eight times less costly than before.

Field (2). Design for simplifying production finds chief expression in mass-produced manufactures. The cheap but efficient motor-car body is a good instance. By large steel pressings and other features, cars were made available to a public which had never aspired to their possession. Other examples are the host of articles made from plastics. By mould design, parts previously machined by hand can be made to serve the same purpose as their expensive prototypes. 'Handmade', an epithet so beloved of the Victorian age, is now less attractive because of its cost.

Field (3) embracing as it does all that the Americans call 'eye-appeal' needs no illustration. All the effects achieved through artistic shape, through colour and through embellishment, are included, and the ease with which ornament can be applied has proved, from the beginning of large scale manufacture and is likely to remain, the most dangerous friend of embellishment. The chief large manufactures in which embellishment plays a leading part are textile fabrics, wallpaper and decorated china. It is in this field that the greatest divergences are to be found, owing to the differences in taste in different communities and in different countries.

*Contact between designer and production*

Design in the first two fields (function and simplification of production) is much more important than in the third; design in these fields differs also from design for 'eye appeal' in another important respect. Both must be carried out in the closest contact with the productive side of the manufacturing firm. Emphasis has been laid elsewhere on the importance of intimate collaboration between the research laboratories and the development departments of factories. The same is true of the design department of a firm dealing with fields (1) and (2) or of any design agency that may be employed. If this is not done, a clever but entirely impracticable pattern or scheme may be submitted.

The designer, even in field (3), should have a working knowledge of the production methods used. There is no need for him to be an expert technician in the sense of being a trained craftsman or mechanic but he should have some practical knowledge of the use of the tools with which his design is to find expression. For instance, in pottery a design suitable for a wall paper or a chintz may not be well suited for a vessel made of clay. Some of the decadence shown by the Chinese ceramic wares of the late 18th and the 19th centuries is due in part to the employment of unsuitable decoration which, while well enough on other media, is out of place on a porcelain vessel. Many of the wares in question were made for the European market, where 'plenty for the money' was sought in the way of embellishment. They conrtast but ill with those made for the Chinese market of that period. Even in the case of textiles and of wall papers, the artist and the technician must understand one another. Realization cannot otherwise be achieved nor can difficulties of expression be overcome. By mutual understanding, adaptations can be brought about which, while in no way spoiling the artist's conception, render technical expression an easier problem. But in the absence of cultivated taste in the public, the efforts of the artist and the technician will be handicapped. In particular, good taste and artistic appreciation must be the qualifications of the wholesale buyer acting as agent for the retail merchant; for the kind of goods that appear in the shop window largely depends on these middlemen.

*Public taste*

Cultivation of taste begins as an essential part of early education. The power of discrimination between good and bad decoration or design can be imparted subconsciously to the receptive mind of the child. A boy or girl who lives in a home with well-designed furniture and amid artistic surroundings, however simple and inexpensive, obtains subconsciously a sense of appreciation and of discrimination. Much can be

done in the school itself and especially in schools of arts and crafts, if discrimination between good and bad art is properly cultivated. The boys and girls they turn out will be the buyers of the future and will demand better artistic value in their purchases. The first step is to teach the teachers in the schools in such a way that they can explain in an interesting fashion why a picture or a design or a shape is good and not merely issue a fiat on the subject.

All these questions are wrapt up in the new educational policy and it is to be hoped that the new Education Act will bring about *inter alia* a new approach in schools and that, like the teaching of musical appreciation which has already made headway, discrimination will be a main plank in the curricula of schools of arts and crafts and a sense of appreciation in schools of all kinds. After all is said and done, 'The test of education is not what children do at school but what men and women enjoy out of it. A people which reserves its religion for Sundays is not religious, and it is not educated if, while it multiplies schools, it takes pleasure in filling its evenings with bad plays, its houses with shoddy furniture and its towns with municipal statuary.' (Final Report of the Adult Education Committee of the Ministry of Reconstruction, 1919.)

### *The Government's function*

Much more could be done to educate public taste by the Government itself and in more than one direction. The Government, through its various Departments, is the largest wholesale buyer in the country and it could set an example by standards of requirement. Those standards could be set with the help of some central design council—a standing commission of the applied arts—on which persons of knowledge and authority in the world of industrial art were conjoined with industrial leaders. Artistic merit could then be added to quality of material and sound construction in the goods purchased out of the taxpayers' money. A lead from a purchaser of such magnitude and importance would have a profound effect on the outlook of manufacturers generally. A beginning has already been made in the typography of official publications.

The Government could do more. Working with the help and guidance of some such central body of advice, British exhibits at foreign fairs could be supervised and new conceptions of British industrial endeavour impressed upon the minds of foreign buyers. The British Industries Fair, the occasion on which purchasers from abroad come to see goods made here, might be radically altered. In the inter-war years a visit to that Fair at many of its stalls was not unlike a visit to a chamber of horrors. In future, it might be made a condition of display that the goods commended themselves to such a standing commission which might also be responsible for organising a permanent exhibition of

British industrial design in some appropriate place in central London, with periodic changes of the exhibits. A start was made in these directions by the appointment of a Council of Art and Industry before World War II and development and extension of its activities might well be the means of bringing about a higher standard of taste in the nation.

Since the foregoing was written the Government has appointed a Council of Industrial Design to take the place of the Council of Art and Industry. The functions of the new Council will be: (*a*) to encourage and assist the establishment and conduct of design centres by industries and to advise the Board of Trade on the grant of financial assistance to these centres; (*b*) to provide a national display of well-designed goods by holding, or participating in, exhibitions and to conduct publicity for good design in other appropriate forms; (*c*) to co-operate with the education authorities and other bodies in matters affecting the training of designers; (*d*) to advise on the design of articles to be purchased by Government departments and other public bodies, and to approve the selection of articles to be shown in United Kingdom pavilions in international exhibitions and in official displays in other exhibitions; (*e*) to be a centre of information and advice both for industry and for Government departments on all matters of industrial art and design.

The grants to the centres will be much on the lines of those made by D.S.I.R. to Research Associations and the functions of the centres will be: (*a*) to study the problem of design in relation to the products of the particular industry; (*b*) to collect and make available to the industry information relating to changes in public taste and trade practice in home and overseas markets and to hold exhibitions at home and overseas; (*c*) to conduct and encourage research and experiment in design of the products of the industry; (*d*) to co-operate with the education authorities and other bodies for the training of designers and in the provision of special equipment, prizes and grants, and to arrange factory visits and training in factories for art students.

The application of science to industry is much in the public eye: the application of art to industry also has its significance.

# APPENDIX I

# SCHEME FOR THE ORGANISATION AND DEVELOPMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

(Cd. 8005)



1. There is a strong concensus of opinion among persons engaged both in science and in industry that a special need exists at the present time for new machinery and for additional State assistance in order to promote and organise scientific research with a view especially to its application to trade and industry. It is well known that many of our industries have since the outbreak of war suffered through our inability to produce at home certain articles and materials required in trade processes, the manufacture of which has become localised abroad, and particularly in Germany, because science has there been more thoroughly and effectively applied to the solution of scientific problems bearing on trade and industry and to the elaboration of economical and improved processes of manufacture. It is impossible to contemplate without considerable apprehension the situation which will arise at the end of the war unless our scientific resources have previously been enlarged and organised to meet it. It appears incontrovertible that if we are to advance or even maintain our industrial position we must as a nation aim at such a development of scientific and industrial research as will place us in a position to expand and strengthen our industries and to compete successfully with the most highly organised of our rivals. The difficulties of advancing on these lines during the war are obvious and are not underestimated, but we cannot hope to improvise an effective system at the moment when hostilities cease, and unless during the present period we are able to make a substantial advance we shall certainly be unable to do what is necessary in the equally difficult period of reconstruction which will follow the war.

2. The present scheme is designed to establish a permanent organisation for the promotion of industrial and scientific research.

It is in no way intended that it should replace or interfere with the arrangements which have been or may be made by the War Office or Admiralty or Ministry of Munitions to obtain scientific advice and investigation in connection with the provision of munitions of war. It is, of course, obvious that at the present moment it is essential that the War

Office, the Admiralty, and the Ministry of Munitions should continue to make their own direct arrangements with scientific men and institutions with the least possible delay.

3. It is clearly desirable that the scheme should operate over the Kingdom as a whole with as little regard as possible to the Tweed and the Irish Channel. The research done should be for the Kingdom as a whole, and there should be complete liberty to utilise the most effective institutions and investigators available, irrespective of their location in England, Wales, Scotland, or Ireland. There must therefore be a single fund for the assistance of research, under a single responsible body.

4. The scheme accordingly provides for the establishment of—

(*a*) A Committee of the Privy Council responsible for the expenditure of any new moneys provided by Parliament for scientific and industrial research;

(*b*) A small Advisory Council responsible to the Committee of Council and composed mainly of eminent scientific men and men actually engaged in industries dependent upon scientific research.

5. The Committee of Council will consist of the Lord President, the Chancellor of the Exchequer, the Secretary for Scotland, the President of the Board of Trade, the President of the Board of Education (who will be Vice-President of the Committee), the Chief Secretary for Ireland, together with such other Ministers and individual Members of the Council as it may be thought desirable to add.

The first non-official Members of the Committee will be—

The Right Hon. Viscount Haldane of Cloan, O.M., K.T., F.R.S.,
The Right Hon. Arthur H. D. Acland, and
The Right Hon. Joseph A. Pease, M.P.

The President of the Board of Education will answer in the House of Commons for the sub-head on the Vote, which will be accounted for by the Treasury under Class IV., Vote 7, "Scientific Investigations, &c."

It is obvious that the organisation and development of research is a matter which greatly affects the public educational systems of the Kingdom. A great part of all research will necessarily be done in Universities and Colleges which are already aided by the State, and the supply and training of a sufficient number of young persons competent to undertake research can only be secured through the public system of education.

6. The primary functions of the Advisory Council will be to advise the Committee of Council on—

(i) proposals for instituting specific researches;
(ii) proposals for establishing or developing special institutions or

departments of existing institutions for the scientific study of problems affecting particular industries and trades;

(iii) the establishment and award of Research Studentships and Fellowships.

The Advisory Council will also be available, if requested, to advise the several Education Departments as to the steps which should be taken for increasing the supply of workers competent to undertake scientific research.

Arrangements will be made by which the Council will keep in close touch with all Government Departments concerned with or interested in scientific research and by which the Council will have regard to the research work which is being done or may be done by the National Physical Laboratory.

7. It is essential that the Advisory Council should act in intimate co-operation with the Royal Society and the existing scientific or professional associations, societies and institutes, as well as with the Universities, Technical Institutions and other institutions in which research is or can be efficiently conducted.

It is proposed to ask the Royal Society and the principal scientific and professional associations, societies and institutes to undertake the function of initiating proposals for the consideration of the Advisory Council, and a regular procedure for inviting and collecting proposals will be established. The Advisory Council will also be at liberty to receive proposals from individuals and themselves to initiate proposals.

All possible means will be used to enlist the interest and secure the co-operation of persons directly engaged in trade and industry.

8. It is contemplated that the Advisory Council will work largely through Sub-Committees reinforced by suitable experts in the particular branch of science or industry concerned. On these Sub-Committees it would be desirable as far as possible to enlist the services of persons actually engaged in scientific trades and manufactures dependent on science.

9. As regards the use or profits of discoveries, the general principle on which grants will be made by the Committee of Council is that discoveries made by institutions, associations, bodies, or individuals in the course of researches aided by public money shall be made available under proper conditions for the public advantage.

10. It is important in order to secure effective working that the Advisory Council should be a small body, but it is recognised that even if full use is made by the Council of its power to work through reinforced Sub-Committees, its membership may be found inadequate to do justice to all the branches of industry in which proposals for research may be made or to the requests of other Government Departments for assist-

ance. It is therefore probable that it will be found necessary to strengthen the Council by appointing additional Members.

The first Members of the Council will be—

The Right Hon. Lord Rayleigh, O.M., F.R.S., LL.D.
Mr. G. T. Beilby, F.R.S., LL.D.
Mr. W. Duddell, F.R.S.
Prof. B. Hopkinson, F.R.S.
Prof. J. A. McClelland, F.R.S.
Prof. R. Meldola, F.R.S.
Mr. R. Threlfall, F.R.S.

With Sir William S. McCormick, LL.D., *as administrative Chairman.*

11. The Advisory Council will proceed to frame a scheme or programme for their own guidance in recommending proposals for research and for the guidance of the Committee of Council in allocating such State funds as may be available. This scheme will naturally be designed to operate over some years in advance, and in framing it the Council must necessarily have due regard to the relative urgency of the problems requiring solution, the supply of trained researchers available for particular pieces of research, and the material facilities in the form of laboratories and equipment which are available or can be provided for specific researches. Such a scheme will naturally be elastic and will require modification from year to year; but it is obviously undesirable that the Council should live "from hand to mouth" or work on the principle of "first come first served", and the recommendations (which for the purpose of estimating they will have to make annually to the Committee of Council) should represent progressive instalments of a considered programme and policy. A large part of their work will be that of examining, selecting, combining, and co-ordinating rather than that of originating. One of their chief functions will be the prevention of overlapping between institutions or individuals engaged in research. They will, on the other hand, be at liberty to initiate proposals and to institute inquiries preliminary to preparing or eliciting proposals for useful research, and in this way they may help to concentrate on problems requiring solution the interest of all persons concerned in the development of all branches of scientific industry.

12. An Annual Report embodying the Report of the Advisory Council will be made to His Majesty by the Committee of Council and laid before Parliament.

13. Office accommodation and staff will be provided for the Committee and Council by the Board of Education.

ARTHUR HENDERSON

23rd July 1915.

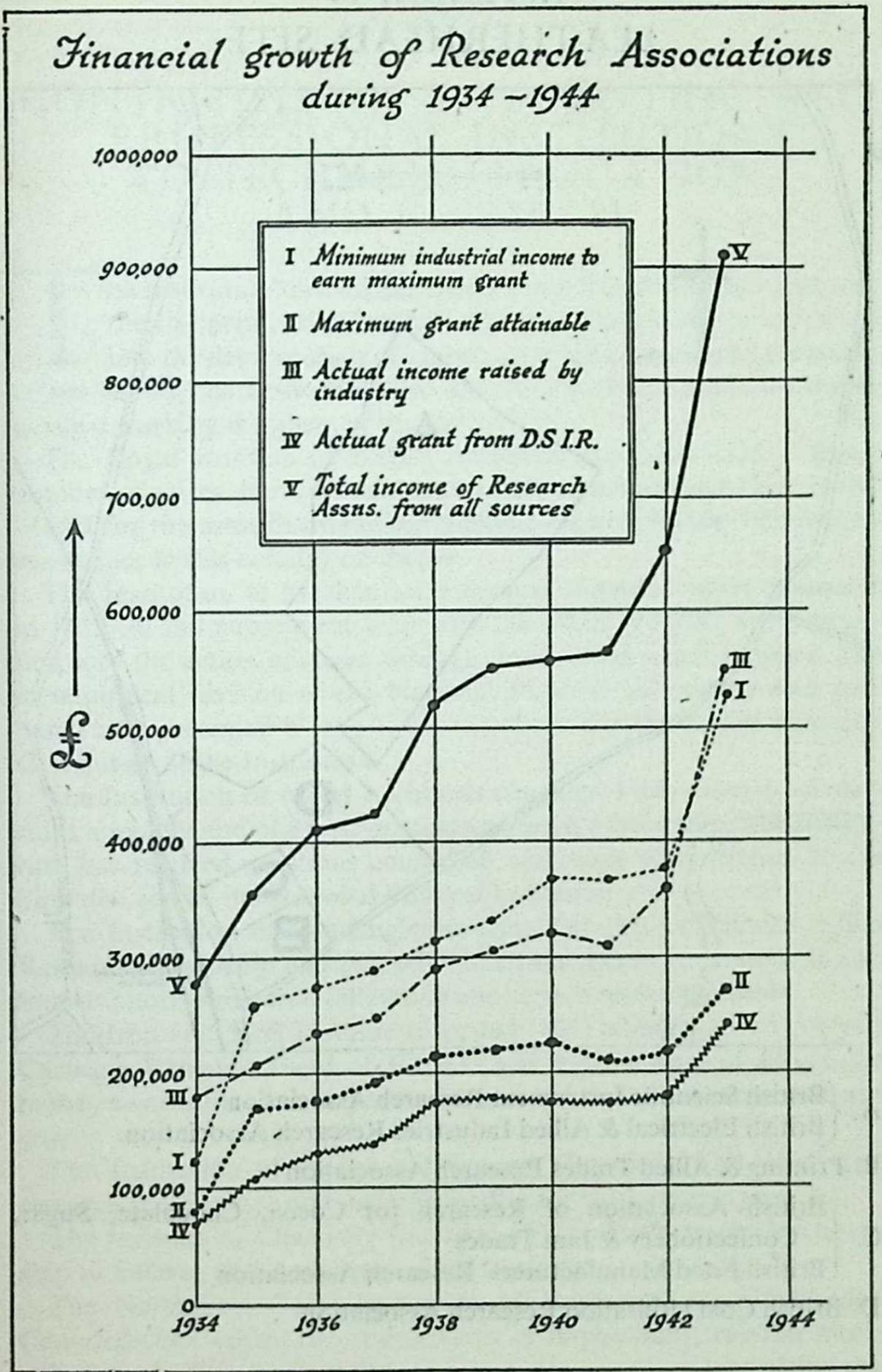
# APPENDIX II

## LIST OF GRANT-AIDED RESEARCH ASSOCIATIONS

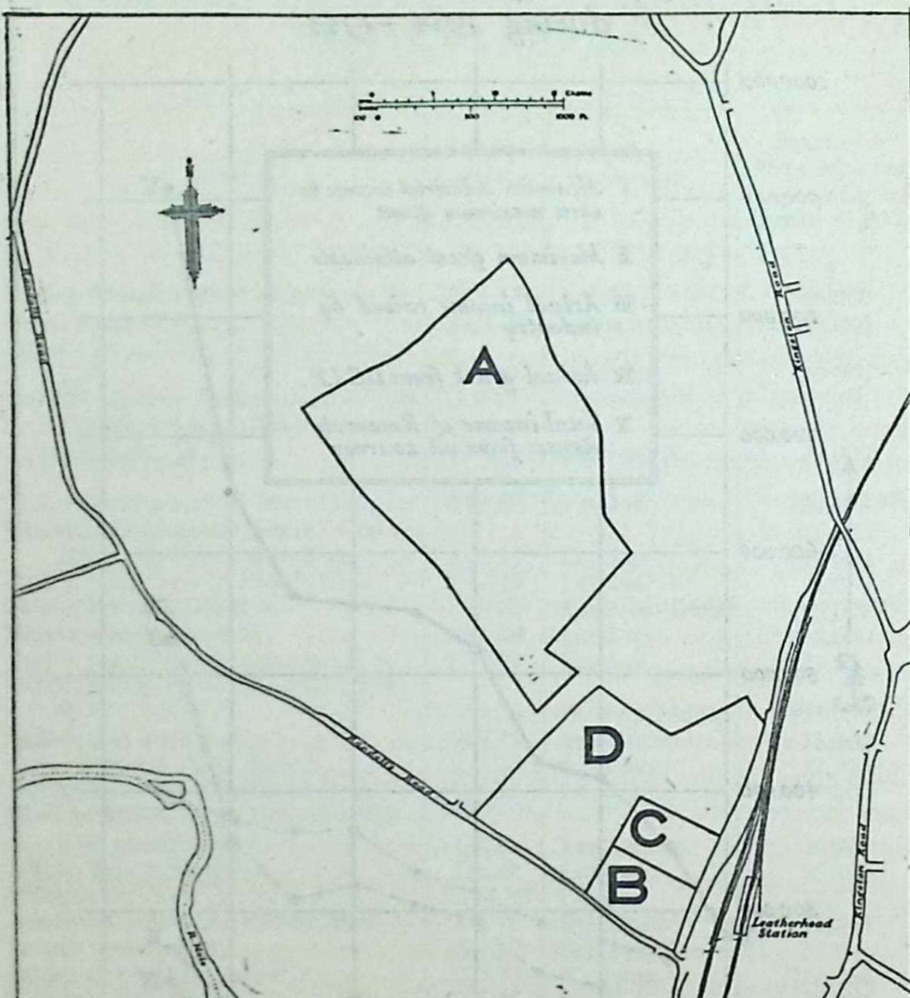
| *Name* | *Date of formation* | *Locality* | *Income for last completed year (to nearest* £1,000) |
|---|---|---|---|
| | | | £ |
| British Scientific Instrument R.A. - | 23.5.18 | London | 16,000 |
| Wool Industries R.A. - - - | 26.9.18 | Leeds | 47,000 |
| British Boot, Shoe & Allied Trades R.A. - - - - - - | 1.5.19 | Kettering | 10,000 |
| British Cotton Industry R.A. (including Rayon & Silk) - - | 7.6.19 | Didsbury | 127,000 |
| Linen Industry R.A. - - - | 10.9.19 | Lambeg, N. Ireland | 28,000 |
| R.A. of British Rubber Manufacturers | 30.9.19 | London | 24,000 |
| Cocoa, Chocolate, Sugar Confectionery & Jam Trades R.A. - | 4.12.19 | London | 12.000 |
| British Non-Ferrous Metals R.A. - | 5.12.19 | London | 46,000 |
| British Refractories R.A. - - | 15.3.20 | Stoke-on-Trent | 25,000 |
| British Launderers R.A. - - - | 19.7.20 | London | 15,000 |
| British Leather Manufacturers R.A. | 27.7.20 | London | 33,000 |
| British Electrical & Allied Industries R.A. - - - - - - | 22.9.20 | Perivale, Mddx. | 138,000 |
| British Cast Iron R.A. - - - | 24.5.21 | Birmingham | 33,000 |
| R.A. of British Flour Millers - - | 31.8.23 | St. Albans | 13,000* |
| British Food Manufacturers R.A. - | 7.1.26 | London | 9.000 |
| R.A. of British Paint, Colour & Varnish Manufacturers - - | 1.9.26 | Teddington | 26,000 |
| British Iron & Steel R.A. - - | 1.1.29 | London | 95,000 |
| Printing & Allied Trades R.A. - | 21.11.30 | London | 23,000 |
| Automobile Research Committee - | 1.7.31 | Brentford | 32,000 |
| British Pottery R.A. - - - | 20.7.37 | Stoke-on-Trent | 25,000 |
| British Coal Utilization R.A. - - | 23.4.38 | Kingston | 212,000 |
| Gas Research Board - - - | 2.5.41 | London | 29,000 |
| British Internal Combustion Engines R.A. - - - - - - | 27.4.43 | Slough | 24,000 |
| British Shipbuilding R.A. - - | 29.4.44 | London | — |
| British Coke R.A. - - - - - | 20.6.44 | London | — |

* For year 1942 : transferred to Ministry of Food for period of the war.

# APPENDIX III



# APPENDIX IV
# LEATHERHEAD SITE




A. British Scientific Instrument Research Association
British Electrical & Allied Industries Research Association.

B. Printing & Allied Trades Research Association

C. British Association of Research for Cocoa, Chocolate, Sugar, Confectionery & Jam Trades
British Food Manufacturers' Research Association

D. British Coal Utilisation Research Association

## APPENDIX V

# CONTRIBUTIONS BY SCIENTIFIC AND PROFESSIONAL INSTITUTIONS TO TECHNICAL EDUCATION AND RESEARCH

The Institution of Civil Engineers (founded 1818) conducted with the co-operation of D.S.I.R. a long and systematic investigation into the deterioration of timber, metal and concrete by the action of sea water. The Institution also awards premiums yearly for distinguished work by members of the Institution.

The Royal Institute of British Architects (founded 1834) offers a number of prizes, bursaries and studentships annually and their Royal Medal for the most distinguished building erected during the previous year either in this country or abroad.

The Institution of Mechanical Engineers (founded 1843) continued in 1919–20 and subsequent years with the aid of D.S.I.R. its investigation into the action of steam through nozzles and steam turbines. The metallurgical division of the National Physical Laboratory also prepared and presented a long series of reports for the Alloys Research Committee of the Institution.

The Institution of Naval Architects (founded 1860) offers 5 scholarships annually and one post-graduate research scholarship. The Institution has referred questions connected with large scale friction to the Ship division of the National Physical Laboratory.

The Institution of Gas Engineers (founded 1863) maintains a Gas Research Fellowship and two scholarships at Leeds University. It also awards another research fellowship and certain research medals.

The Iron and Steel Institute (founded 1869) administers an Andrew Carnegie Research Fund of £20,000 and a prize fund of £3,000 for money awards for the best papers on iron and steel manufactures in any year.

The Institution of Electrical Engineers (founded 1870) offers two research scholarships and one scholarship for works employees.

The Institute of Chemistry (founded 1877) offers a research scholarship to Fellows and Associates of the Institute.

The North-East Coast Institution of Engineers and Shipbuilders (founded 1884) offers two scholarships in shipbuilding, marine, mechanical or electrical engineering, one annually, the other triennially, and

a gold medal (biennially) to a member of the Institution for ability to take a share in control of industry.

The Institution of Mining and Metallurgy (founded 1892) awards gold medals for distinguished work.

The Institute of Metals (founded 1908) investigated, in the 1920's in co-operation with D.S.I.R., the cause and prevention of corrosion in aluminium and its alloys.

The Institution of Structural Engineers (founded 1908) holds competitions from time to time for the award of prizes and medals.

The Institute of Transport (founded 1919) offers gold and silver medals and a premium for a paper by a graduate or a student.

The Institute of Fuel (founded 1927) offers two medals annually—(i) the Student's gold medal open to competition and awarded if the necessary standard is reached, and (ii) the Melchelt bronze medal, the recipient being invited to give the Melchelt lecture before the award.

# APPENDIX VI
# CITY COMPANIES

The following City Companies in addition to those mentioned in the text have also done much to promote technical education and industrial research as briefly indicated below:

*The Armourers and Brasiers* contribute 100 guineas a year to the City and Guilds of London Institute. Previous to World War II and the serious losses caused by the enemy in the bombing of the City, they were active and generous benefactors by scholarships for engineering (including aeronautics) and metallurgical research. They also founded bursaries for apprentices in engineering. All these activities have had to be abandoned. They still grant £100 p.a. to Sheffield University and co-operate with the Trades Societies of Sheffield and the Master Cutler in granting prizes and diplomas to operatives in iron, steel and allied industries for new ideas. They also grant a bursary for two years to an apprentice in metal works in Birmingham.

*The Bakers* have encouraged technical education by the award of Exhibitions at the National School of Bakery, Borough Polytechnic Institute, London, and presentation of the Freedom of the Company to prizewinners. They also promoted medals to prizewinners at the Bakers' Annual Exhibition at the City and Guilds of London Institute. (These activities have had to be curtailed in recent years as the result of enemy action.)

*The Brewers' Hall*, destroyed by enemy action in 1940, was the headquarters of the Institute of Brewing and represented the headquarters of the scientific side of the trade (*see* p. 47.)

*The Carpenters* in 1893 opened their Trades Training School in Great Titchfield Street under the direction of Prof. Banister Fletcher. Since then the Company, in association with the Companies of Armourers and Brasiers, Glaziers, Joiners, Pewterers, Plaisterers, Painters and Stainers, Tylers and Bricklayers, and Wheelwrights, has given free practical instruction in all branches of the building trade. On the outbreak of World War II the Company offered their training facilities to the Government, and since January 1940 some thousands of soldiers have been trained as carpenters, joiners, heavy timber men, blacksmiths and sheet metal workers. A special class was for a time opened for special welding instruction at the request of the Plumbers' Union.

Up to 1938 lectures by professional men were given in Carpenters' Hall on carpentry and joinery, building construction and sanitation.

Annual examinations were held in these subjects and in addition to their grant on the foundation of the City and Guilds of London Institute the Company gives prizes for carpentry and joinery to that foundation.

*The Clockmakers* contribute to the funds of the British Horological Institute, and offer two scholarships of £40 tenable for three years for students in Horology and Light Engineering at the Northampton Polytechnic Institute.

*The Coachmakers* as early as 1865 offered prizes in connexion with the examinations of the Government Department of Science and Art, and for years they have sought to encourage technical education and creative design by exhibitions.

*The Cordwainers* assisted in the maintenance of the Leather Trade School opened in 1887 and maintained by the Leathersellers, the City and Guilds of London Institute and the Boot and Shoe Manufacturers' Association. In 1908 with the assistance of the L.C.C. the Company established the Cordwainers' Technical College, for all branches of the boot and shoe industry and leather goods manufacturers. The Company contributed £1,250 on the foundation of the City and Guilds of London Institute and make an annual grant to the Institute and to the Boot, Shoe and Allied Trades Research Association.

*The Cutlers*, besides maintaining scholarships and exhibitions at Oxford, Cambridge, London and Sheffield Universities, have spent liberally on technical education since the middle of the nineteenth century. For some years the Company has contributed generously to the City and Guilds of London Institute, and has taken a keen and practical interest in the apprenticeship of youths in the surgical instrument making industry.

*The Dyers* before, and since World War I, have encouraged research in colour chemistry.

*The Farriers* hold examinations on the theory and practice of farriery and grant diplomas as Registered Shoeing Smith (R.S.S.); also examinations for higher diplomas.

*The Feltmakers* offer for competition a gold medal with diploma and a cash payment of £50 open to authors of 'papers embodying the results of scientific research or technical investigation connected with the art of feltmaking'. This is intended as a first step in support of a co-operative Research Association in course of establishment by firms engaged in the industry, who are members of a research committee appointed by the Company.

*The Founders* award two annual fellowships of £250 each which are available to promising graduates to follow any course most necessary for some branch of the industry. It may include research or a period in works either at home or abroad. The Company also grant three scholar-

ships of £40 a year each tenable for 3 years in engineering at King's College, London. They have also held competitive examinations and awarded money prizes, medals and certificates for success in the craft.

*The Glaziers*, besides taking a share in the Carpenters' Trade Training School, became a member of the Society of Glass Technology at the University of Sheffield in 1918 and a scheme was drawn up to meet the needs of post-war conditions of the trade.

*The Leathersellers* in 1894 inaugurated technical classes in connexion with the leather industries at Herolds' Institute, Drummond Road, Bermondsey, and in the following years the Company made annual grants of £500 for a permanent Tanning School. In 1909 the Company purchased a site in Tower Bridge Road, Bermondsey, and erected at a total cost of £25,500 the Leathersellers' Technical College, providing facilities for complete instruction in all branches of leather manufacture. In 1913 and 1914 the Company made additions to the buildings and the College was further enlarged in 1919 and 1930. They made an annual grant towards the work of the City and Guilds of London Institute from its foundation in 1878 until 1919. In 1938 they made a special donation of £250 to the Institute in commemoration of the centenary of the birth of Sir William Henry Perkin, discoverer of the aniline dye, founder of the coal tar industry, and Master of the Company 1896–97.

*The Paviors* founded in 1928 and maintain a part-time professorship of Highway Engineering at the Imperial College of Science and Technology.

*The Plaisterers* make a small contribution to the Trades Training School owned by the Carpenters. They offer prizes to art workers in the trade with which they are connected and also subscribe £100 a year to the City and Guilds of London Institute.

*The Spectacle Makers* have an examination scheme of a high standard for sight testing opticians and they have about 4,000 highly trained opticians on their register. Holders of their diploma are recognised by the Ministry of Health as qualified for the testing of sight and the supply of spectacles in connexion with the National Health Service.

*The Stationers* established before World War II a Technical Board representing the printing industry and kindred trades which arranged for lectures on subjects connected with the craft, and held examinations and awarded prizes and certificates. Its future is not yet determined.

*The Tin Plate Workers and Wire Workers* award a Bursary at Sheffield University.

*The Turners* since 1870 have held regular public exhibitions of turnery (metal, wood and ivory in both plain and ornamental turning) at which medals and prizes are awarded to professionals, amateurs and craft schools. Awards for skill in pottery have recently been introduced. Lathes were distributed to a number of schools and institutions in 1913.

# APPENDIX VII

## QUALITY CONTROL

### BY SIR FRANK GILL, K.C.M.G.

For the purpose of manufacture it is necessary to define the qualities which are to be found in the articles made and in the piece-parts which compose the articles. These qualities may be expressed as dimensions, weights, composition, or even by comparison with a sample.

Consequently in the course of manufacture it is imperative to supervise the quality of the things being made, because only the items which are correct will count as effective production, be accepted and paid for. The others will be rejected, and even if rectified and accepted later, only at the expense of additional effort.

When the quantities manufactured increase it becomes desirable to assemble components from interchangeable piece-parts which are not made to exact dimensions, etc., but to requirements plus or minus a tolerance, because it is impracticable to make things all exactly alike. As an example, a particular part of a machine is acceptable if between ·080 in. and ·084 in., and this is sometimes expressed as ·082 in. plus or minus ·002 in.

Long ago it was believed that parts could be made to exact dimensions and so be interchangeable, but this was found unworkable. Then the 'Go' gauge was introduced which ensured that the part was not larger than the dimension required by more than a permitted limit. Curiously, this practice prevailed for many years until the 'No Go' gauge was added, and since then the use of these two gauges has ensured that the part is held within the limits permitted.

It is the custom of inspectors to require that piece-charts of articles manufactured shall be inspected at the intermediate and final stages, and frequently 100 per cent inspection is called for, meaning thereby that each article is to be submitted to the appropriate inspection. With large-scale manufacture, 100 per cent inspection becomes very costly, while on the other hand, the inspector is properly desirous not to accept any defective material, partly because of the delay to assembly, but mainly because of the harm which may be caused by defective parts going into service.

When manufacture begins the persons responsible may find that owing to various causes the defective product is greater in quantity than seems proper. It may be that the existing shop equipment will not permit of turning out work in accordance with the tolerances prescribed,

or perhaps there are troubles with the equipment which can be cured; or again there may be some difficulty with the material. Often these definite causes of trouble can be traced and cured; but if not, it may be necessary either to change the manufacturing process or to have the specification altered so as to bring the conditions within the limits of what the production organisation can accomplish. Under these circumstances, how is the manufacturer to know what he really can do—when to persist in his efforts to produce parts to finer limits, or when to review his whole process?

A further problem is set by munitions of war. In many cases military stores can only be tested by destruction, and therefore it is obvious that 100 per cent of the shells, fuses, grenades and ammunition cannot be tested destructively; and yet they are things which, if accepted in a defective condition, may do much harm to life and equipment in one's own forces, while being ineffective in the destruction of the enemy. In such cases, when say 20 per cent of the articles have been destroyed by testing, a good deal is known about those destroyed. But this is not of much value; it is necessary to know the qualities of the 80 per cent which have not been tested. If a reliable method can be found for testing by samples in these very dangerous cases, cannot the same technique be employed in the cases which are non-dangerous, in order to make the effort of inspection less onerous? The study of statistics based on probabilities and applied to the technique of inspection has provided the solution to these questions.

It is not the purpose of this sketch to give technical details of the method, but rather to show the principles used, what the method can do. How to set about answering the question: 'Shall we put Quality Control into our Works?'

In manufacture by automatic machine tools, the machine tool is 'set' to do a specific operation within a plus or minus tolerance, and when the toolsetter has this right and the inspector is satisfied,* production may begin. The setter keeps himself advised as to the quality being turned out and, as he judges necessary, readjusts the machine tool. The underlying idea is that if the machine tool is right the product will be right, and of course very much good work has been done along these lines. But even machine tools are not permanent, and the check by the setter is rather like applying a governor to a steam engine only when thought necessary, and then adjusting the speed accordingly.

This existing method is only partly preventative and usually the results are not analysed in bulk for the benefit of the future.

* A control chart, made from a sample of, say 50, successively made parts, forms a convenient way of checking the setting, both for variability and for centre of distribution.

Under the traditional inspection technique the emphasis is placed upon the individual piece, and the question is: 'Does this part have the qualities required?' If the answer is 'Yes' the part is accepted for the next process or finally; but if the answer is 'No' it is either rejected outright or passed to rectification, after which it again goes through inspection.

Under Quality Control inspection the emphasis is quite different; it is placed not on the individual piece but on the current flow of the product. The question is: 'Does the batch, from which this sample came, have the qualities required?' and to answer this question the results of the inspection of small samples are submitted to constant analysis at frequent and regular intervals during the course of production. The analysis is directed towards four objectives:

1. To ensure that the qualities of the product are almost entirely within the limits specified.

2. To give timely warning of impending trouble before trouble actually arises.

3. To provide a means of detecting and eliminating assignable cases of variability that need not be left to chance, and of avoiding expenditure of effort on small differences due to chance, which it is not economical to endeavour to cure.

4. To keep the probability of defective parts below an assigned value, at which complete inspection is unnecessary and uneconomical.

If a very large number of parts are taken and the qualities embodied in the product of a machine tool in the new condition and in different stages of wear are ascertained, it is found that, in any reasonable condition, a predominating number of the dimensions are clustered about the average dimension, and the number of deviations from the average become less frequent as the amount of the deviation increases. Fig. 1

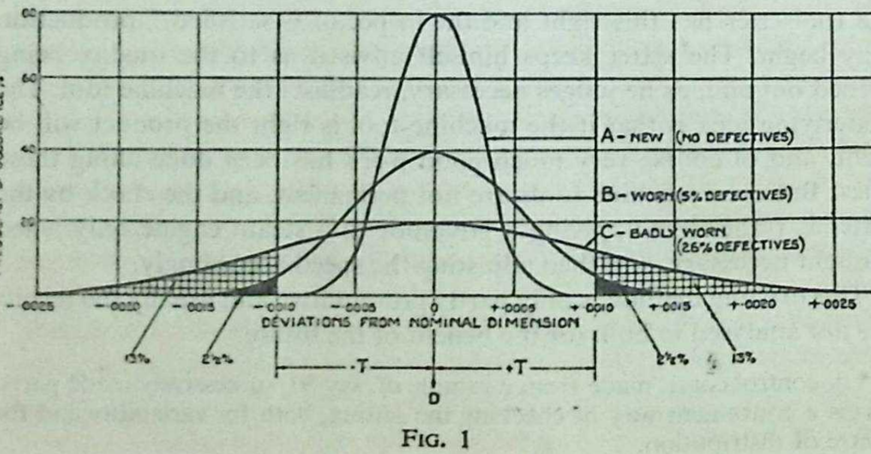



FIG. 1

shows this distribution. The average should in general be approximately at the point midway between the tolerance limits.

The tolerance is shown as ·0010 in. each side of the average, and while the new condition prevails and there are no assignable causes producing trouble, the machine produces parts which are all within the tolerance limits. When, however, wear has reached the stage shown at B, the curve has modified its shape, the frequency at the average is less, while the base is broader and in this stage the machine is producing 2½ per cent rejects on each side of the average. If the wear persists to the much worn stage (shown at C) the dispersion is still greater, and now the rejects are 26 per cent of the gross products. Of course these changes do not usually happen suddenly, but if the extent to which wear was impending had been known, measures could have been taken early to correct matters before the stages B and C were reached and rejects were produced.

*How is Quality Control worked in practice?**

The key to Quality Control lies in statistical knowledge and particularly in the matter of probabilities, but as with so many applications of science, no one need be deterred from using an instrument or a technique because he is not familiar with the science underlying its construction. Many people who use watches, radio sets, field glasses, etc., know the simple rules for operating these things, and these rules will enable non-technical persons to obtain a great value from their use, even if they must proceed further in order to enjoy the fullest value which the instrument can give.

The following is an actual illustration of the application of Quality Control technique to the manufacture of a small piece-part. Measurement in this case was applied to the samples; they were not tested by a 'Go No-Go' gauge. The piece-part had a dimension which was to be held within the limits ·080 in. and ·084 in. Every hour four piece-parts were taken as a sample, each of the four was measured and the average was plotted on a chart showing both the order in which the samples were taken and the average dimensions. The extreme range of all the dimensions was from ·0809 in. to ·0840 in.; the average was ·0828 in. instead of ·0820 in., with the consequential result that although all of the parts were within the tolerance limits, there was a larger margin on the minus tolerance side and no margin on the plus side; there was therefore a danger of running beyond the limit on that side.

The second step was to analyse the results of the 36 samples and show on the chart control lines (marked *d* on Fig. 2), which define the upper

* For brevity, these remarks are confined to Quality Control by the method of variables i.e. in which measurements of parts are made.

and lower limits within which the sample plots should fall, on the assumption that the variations between plots were all determined by chance and not by removable (or assignable) causes.

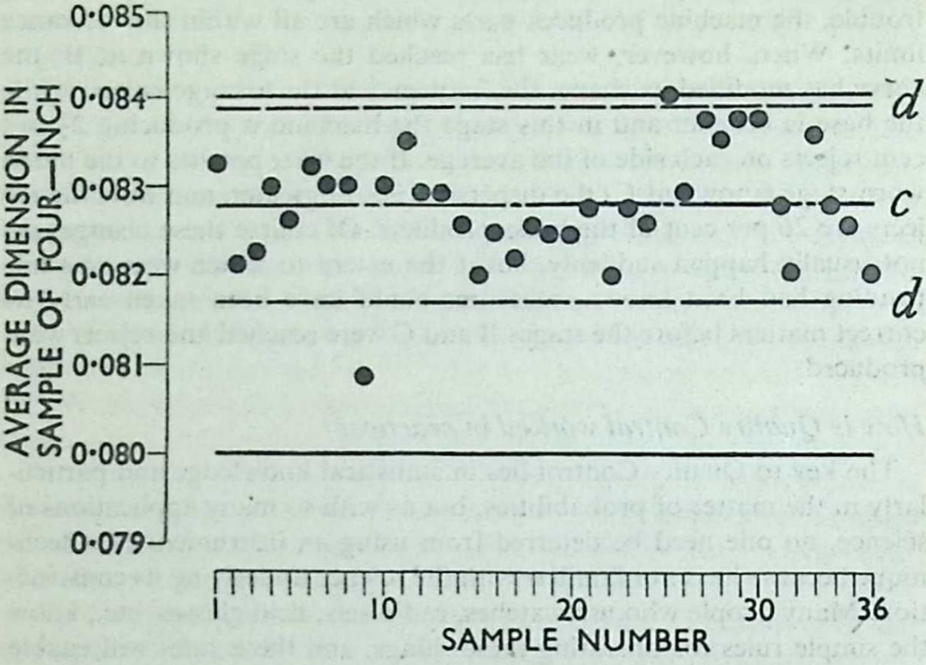



FIG. 2

The control lines in effect separate out the chance variations (outside the control lines), which it is not economical to follow up and try to remove, from the variations due to assignable causes (inside the control lines) on which action should at once be taken in order to investigate and remove the cause. Thus any plot appearing on a control line or between it and a tolerance limit is a warning of impending rejections. In this case the next step must be to reset the machine to make the average dimension ·0820 in. in order to make the margins between the control lines and the tolerance limits symmetrical.

The chart (in two parts, viz., for averages and ranges), is preferably kept near the machine tool—suitably protected against oil, etc., and open to inspection by all concerned; the samples should be taken regularly as prescribed in numbers and time-intervals; the averages and ranges (the difference between the largest and smallest of each sample of 4) should be entered on the chart in the order in which they were taken within a few minutes of obtaining the data. The charts should not be a drawing office matter; all should be done on the spot, the object being to show the average dimensions which are currently being pro-

duced by the machine in question under as much the same conditions as possible. If more than one machine produces the same kind of work there will be a chart for each machine tool. The controls are fixed by a quite simple routine which takes care of the statistical requirements and is not an involved matter.

*Results which may be expected from Quality Control successfully applied.*

In many cases where it is difficult to maintain repetition work within the required limits, Quality Control should bring the production within the limits and so reduce the wastage of material and effort due to rejects. For the same reason it increases the effective production of good parts. It reduces the upsets which occur in shops when things go wrong and search is made into all kinds of matters in the endeavour to find the reasons. It introduces better co-operation between Inspection and Production; it is an important means of keeping down rejects due to 'green' labour; it should reduce the cost of inspection if its use is appreciated by those who control inspection.

The cost of applying Quality Control is negligible. At first there may be a few persons added for the work of charting, etc.; but while the work on each part is greater, the number of parts inspected ought to be less and the saving in effort and material wasted on rejects should produce a net saving, not a greater cost.

*First steps*

(1) To study War Emergency Publication No. B.S. 1008, 1942, of the British Standards Institution. This Standard is simple, direct and written from the factory man's point of view.

(2) To consider which of the products on which the factory is engaged is suitable for the use of Quality Control. Obviously the first thought is of repetition work, whether continuous flow or in batches of considerable size.

(3) To answer the question: 'Which cases and how many for a start?' The short answer seems to be—Look for cases where the rejects are high; select a few of the most troublesome of these and set up charts for very few, say not more than two or three at first.

(4) To explain fully to all concerned what is being done and what is aimed at; the explanation should be so full that the element of surprise (so often the cause of misunderstanding) will be absent.

(5) As soon as convenient, to draft detailed written instructions for each step and each class of shop personnel concerned.

(6) To begin plotting charts of the selected processes for a few days

without putting in the control limits. Where no queries arise, perhaps one week will be sufficient.

(7) To use the average of the averages and the average range given by the trial period; and to set up the control limits and maintain the charts.

(8) To introduce Quality Control gradually in those places where it is appropriate as a regular part of the factory routine.

In all this it is usually better to employ an intelligent person in the Inspection Department, thoroughly familiar with workshop conditions, rather than to employ a statistician who is not familiar with shop conditions.

*Conclusion*

Many persons say: 'We have used Quality Control for years', really meaning that they have used methods for controlling quality, but not Quality Control as herein defined. The marks which distinguish Quality Control from all other methods seem to be:

(1) Regular measurement of small samples.

(2) Instant charting of results of sampling.

(3) Control limits fixed by statistical method, not by guesswork.

(4) Exhibition of charts where the production force can easily fulfil their duty of interpreting the information from them and deciding when to take action. It would not be of much use for the railway signals engineer to provide perfect signals unless the driver of the train could see them and realise his duty to obey them.

Inspectors following this method will enlarge their role from that of merely guarding the quality of products to that of assisting production —a more satisfying function.

Increased production is not to be obtained merely by encouraging shouts from onlookers urging more effort and longer hours. It is also affected by expert planning, the maintenance of smooth unbroken flow of materials, machine tools, labour, orders and the use of best methods, and one of these—in the appropriate cases—is Quality Control. In the first instance the burden of investigation and application of this new aid lies with the managements of factories and those managements now have the means to push this matter with all the intense energy that the need for greater efficiency demands.

## SHORT BIBLIOGRAPHY


| *Title* | *Published by* |
| --- | --- |
| War Emergency Publication No. *B.S.* 1008, 1942, 'QUALITY CONTROL', being a copy of American Defence Emergency Standards Z1.1, 1941 and Z1.2, 1941 and Appendices. | British Standards Institution, 28 Victoria Street, S.W. 1. |
| American War Standard Z1.3, 1942. 'Control Chart Method of Controlling Quality During Production', April 1942. | American Standards Association (copies available at B.S.I.). |
| 'A First Guide to Quality Control for Engineers', Sept. 1943. Ministry of Supply Handbook. | Ministry of Supply, Advisory Service on Quality Control, C.P.R.S.D. (S.R. 17), Berkeley Court, Glentworth Street, N.W.1 |
| 'Quality Control Chart Technique when Manufacturing to a Specification', by B. P. Dudding and W. J. Jennett. | The General Electric Co. Ltd., of England, Magnet House, Kingsway, W.C. 2. |
| British Standard 600R, 1942. 'Quality Control Charts', by B. P. Dudding and W. J. Jennett. | British Standards Institution, 28 Victoria Street, S.W. 1. |
| 'Quality Control in Production', by H. Rissik. | Sir Isaac Pitman & Sons Ltd., 39 Parker Street, W.C. 2. (In the Press.) |
| A.S.T.M. Manual on Presentation of Data (reprinted March 1941). | American Society for Testing Materials. Philadelphia. (available at B.S.I. library.) |

# INDEX